Pilot Study to Evaluate the Practicality of Aquatic Ecosystem Monitoring in Small Agricultural Streams in Alberta

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Pilot Study to Evaluate the Practicality of Aquatic Ecosystem Monitoring in Small Agricultural Streams in Alberta

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Environmental Assurance
Alberta Environment

March 2009

W0901

ISBN: 978-0-7785-8106-2 (Printed Edition)
ISBN: 978-0-7785-8107-9 (On-Line Edition)
Web Site: http://environment.gov.ab.ca/info/home.asp

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EXECUTIVE SUMMARY

Monitoring, evaluation and reporting on aquatic ecosystem health are implicit requirements of the government of Alberta *Water for Life* commitment to assure *"healthy aquatic ecosystems"* (HAE). In addition to water quality monitoring, an increasing amount of monitoring of sediment quality and biological communities has occurred in recent years on major rivers, but comparable monitoring efforts on small streams have been very limited.

A pilot study was conducted on three streams from an existing water quality network of agricultural streams (i.e., the Alberta Environmentally Sustainable Agriculture or AESA network) to evaluate the feasibility and practicality of including sediment and non-fish biota monitoring. In fall 2006 AESA sampling locations on Rose Creek, the Blindman River and Strawberry Creek were sampled for benthic invertebrates (kick nets), epilithic and planktonic algae (community analysis and chlorophyll-a) and bottom sediments (nutrients and particle size). Field measurements and observations were taken of basic water quality parameters, hydrometric features, and reach, stream and bank characteristics.

The three watersheds are located in different, although adjacent ecoregions, and they are farmed with a different level of intensity. The Rose Creek site is more erosional in nature, and has lower dissolved nutrient levels and higher flows than the Blindman River and especially Strawberry Creek. Riparian damage due to cattle access was particularly evident at the Blindman River site.

Sampling of biological communities and sediments from small streams proved to be feasible and practical. However, sampling techniques and the type of field information differ significantly from those routinely obtained from larger provincial rivers. Therefore it would be important to invest in staff training if stream sampling was to be carried out routinely.

Benthic invertebrate and epilithic algal communities comprised many taxonomic groups for which ecological requirements and responses to various forms of disturbance are fairly well understood. The distribution of such organisms has been used elsewhere to develop indicators which in turn have been used to assess the 'health' or 'integrity' of aquatic ecosystems. Even at the scale of this pilot study it was possible to note differences in biological communities among streams that were linked to the degree of eutrophication (e.g., nutrient levels and dissolved oxygen conditions), and physical habitat characteristics and disturbance. Phytoplankton communities were not very diverse and appeared to have less potential for future monitoring programs.

One of the difficulties in assessing aquatic ecosystem health in Alberta lies in defining 'healthy' aquatic ecosystems. One approach is to use 'natural or least impacted' conditions, to define 'background' or 'reference conditions' and use these as a depiction of healthy conditions, for a given eco-region. To capture variability within an ecoregion,

researchers advocate sampling about 20 carefully selected sites for 2 to 3 years. Applied to Alberta, 80 streams would have to be sampled to cover the four main ecoregions with agricultural activity. The effort is substantial, but would allow the description of expectations of 'healthy' conditions, which in turn would enable the definition of bio-criteria. Such information is basic to health assessments of agricultural streams and similar streams influenced by other types of human activities (e.g., forestry, mining, urban development).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACKNOWLEDGEMENTS

Water for Life, Aquatic Ecosystem Health working group provided funding to process sediment and biological samples.

Epilithic chlorophyll-*a* and sediment chemistry samples were analyzed at the Analytical Chemistry Laboratory of the Alberta Research Council in Vegreville under supervision of Frank Skinner. Dr. Michael Agbeti (Bio-Limno Research & Consulting Inc.) Halifax, Nova Scotia identified and enumerated epilithic algae. William J. Anderson, Spruce Grove, Alberta sorted, identified and enumerated benthic invertebrates.

Mary Raven finalized figures and tables and formatted the report.

T. Hebben and R. Zurawell (Alberta Environment) provided valuable comments on the algal monitoring and L.R. Noton (Alberta Environment) reviewed the report.

1.0 BACKGROUND

Monitoring, evaluation and reporting on aquatic ecosystem health are required to assure the Government of Alberta *Water for Life* (WFL) commitment of *"healthy aquatic ecosystems."* Healthy aquatic ecosystems (HAE) can be defined as functioning and diverse systems of biological communities (primary producers, invertebrates and vertebrates) interacting with an adequate chemical (water and sediment quality) and physical environment (hydrology, channel processes, riparian zones) (e.g., Whitford 2005).

In Alberta, provincial-scale monitoring of aquatic ecosystem health (AEH) has focused primarily on surface water quality of rivers and lakes. Expansion of provincial networks and programs to include sediment quality and non-fish biota (e.g., benthic invertebrates, and other aquatic biota) of rivers, streams, lakes and wetlands is required to support WFL goals. The development of such monitoring programs requires selection of practical and efficacious sampling methods, sample processing and data management procedures, and appropriate indicators of aquatic ecosystem health.

Monitoring, evaluating and reporting on the diverse range of aquatic ecosystems and human influences on a provincial scale represent a complex and costly undertaking. To maximize efficiencies and control costs, North South Consulting Inc. et al (2007) recommend building on existing monitoring networks, which already provide information on some AEH components.

The Alberta Environmentally Sustainable Agriculture (AESA) stream water quality sampling program has involved monitoring of 23 streams and was designed to document the effects of agriculture on stream water quality over time. The AESA network comprised streams selected based on similarities in soils and landscapes attributes of their watersheds and the range of agricultural intensities and practices in these watersheds (Anderson et al. 1999). The AESA program focused on surface water quality indicators known to be influenced by agricultural intensity (e.g., nutrients, pesticides, bacteria) (e.g., Anderson et al.1998), but did not include other measures of AEH.

2.0 OBJECTIVES

The intent of this small pilot project was to scope the feasibility of adding sediment and non-fish biota to AESA stream monitoring and to make a preliminary evaluation of the data.

Specific objectives were to:

- Test the suitability and practicality of monitoring techniques at a few sites;
- Provide some preliminary information for sediment chemistry and biological communities;
- Produce recommendations for future AEH monitoring of agricultural streams.

3.0 METHODS

3.1 Sampling Sites

The pilot study, which took place in August - September 2006, focussed on three agricultural streams: Strawberry Creek and the Blindman River in the Boreal Transition ecoregion and Rose Creek in the Western Alberta Upland. The original classification of agricultural intensity relied on 1991 Statistics Canada census data (Anderson et al.1998) data pertaining to chemical and fertilizer expenses and manure production and the drainage basins spanned the range of agricultural intensity: "low" (Rose Creek), "moderate" (Blindman River) and "high" (Strawberry) (Table 1, Figure 1). Census data from 1996, 2001 and 2006 indicate that agricultural intensity in the Blindman River drainage basin has fluctuated between "medium" and "high", while that in Strawberry Creek has fluctuated between "high" and "medium" (Lorenz et al., 2008(draft). Blindman retains a "medium" rating, but Strawberry Creek is now also rated as "medium". Nutrient levels, particularly dissolved nutrients, for the period of record (Table 1) are generally lowest in Rose and highest in Strawberry Creek, a situation which has been documented in every year of monitoring (e.g., Anderson et al. 1998, Anderson 1997, 1998, Carle 2001, Depoe and Westbrook 2003, Depoe, 2004, Depoe 2006 a,b, Lorenz et al., 2008(draft).

Sampling of sediments and biological community took place near the Water Survey of Canada gauging station which has also been the marker for the water quality sampling sites.

Table 1 Summary of background information on the three AESA streams selected for the pilot study

	ROSE CREEK	BLINDMAN RIVER	STRAWBERRY CREEK
Drainage basin size (km^2)	559	353	592
Ecoregion	Western Alberta Upland	Boreal Transition	Boreal Transition
Major watershed	North Saskatchewan River	Red Deer River	North Saskatchewan River
Agricultural Intensity			
Anderson et al. (1999) based on 1991 census	Low	Medium	High
Lorenz and Depoe(2009) ('average' of 1996, 2001,2006 census)	Low	Medium	Medium
Mean daily discharge 2006 (cms)	1.372	0.559	0.326
Nutrient Concentrations (mg/L) (Lorenz et al. draft)	Nutrient data from 1995 to 2006		
	Minimum-Median-Maximum	Minimum-Median-Maximum	Minimum-Median-Maximum
TP	0.062 0.234 0.955	0.136 0.297 0.536	0.189 0.692 1.249
TDP	0.018 0.030 0.058	0.058 0.152 0.338	0.047 0.0127 0.319
TN	0.900 1.332 2.551	1.305 1.973 3.495	1.186 3.296 4.628
TKN	0.862 1.276 2.453	1.079 1.702 2.857	0.894 2.516 3.203
$(NO_2 + NO_3)$-N	0.011 0.016 0.036	0.032 0.130 0.271	0.136 0.367 0.859
(NH_4^+)-N	0.023 0.054 0.084	0.061 0.227 0.560	0.075 0.387 0.756

Figure 1 Agricultural watersheds monitored under the Alberta Environmentally Sustainable Agriculture (AESA) program

3.2 Sampling Methods

3.2.1 *Field Measurements*

Field measurements and observations, based on Barbour et al. 1999, Jones et al. 2004, and Stambaugh et al. 2006 protocols were carried out at each site. The sampling reach was defined as 6 times bank full width, and three transects were established: Transect (T1) at the lower (downstream) end of the reach, T2 in the middle and T3 at the upper (upstream) end. Wetted width, bank full width, depth, mean flow velocity were measured along each transect; instantaneous discharge was estimated from these measurements. Multi-probe readings of DO, percent DO saturation, conductivity, pH and temperature were recorded along five points on T1. Water samples were collected from that reach. Reach characteristics such as stream nature (i.e., riffle, run, pool or pool/back eddy), % macrophyte coverage and dominant taxa, substrate composition (e.g., % cobble, gravel, sand based on visual estimates) and substrate embeddedness were recorded for each transect. Bank characteristics such as bank stability, degree of undercutting, dominant riparian vegetation and terrestrial canopy cover were recorded for a 10 m strip centered on each transect. A summary of field observations recorded during the pilot is provided in Appendix 1.

3.2.2 *Benthic Invertebrates*

D-frame kick nets were used to collect invertebrates. One-minute kick samples were collected at each of the three transects for the study reach. Sampling was carried out by kicking the substrate, and moving in an upstream direction across the channel while sweeping the net over the disturbed substrate. If the net appeared to clog, sampling was interrupted; the net emptied and sampling resumed for the remainder of the time. The three one-minute transect samples were combined to form one composite sample per study reach. Although most of Alberta Environment's (AENV) benthic invertebrate monitoring of large rivers has relied on nets of 210 µm mesh size, rapid assessment procedures which are popular in some Canadian and US monitoring programs of smaller streams (e.g., Jones et al. 2004) use much coarser mesh sizes. To evaluate the relative merits of invertebrate data obtained with different mesh sizes, two sets of nets (210 µm and 400 µm mesh size) were used at each site.

Samples were transferred to plastic bags and preserved with buffered formaldehyde shortly after collection. Three replicate samples were collected with each net at the Blindman River site to describe variability. Each replicate consisted of three one-minute kicks collected along each transect and pooled to form a composite sample.

3.2.3 *Epilithic Algae*

Epilithic algae for chlorophyll-*a* determination were scraped from rocks using the template method (Alberta Environment 2006). Scrapings from a 4 cm^2 template were taken from each of three rocks taken to form a replicate sample. A replicate sample was generated along each transect, yielding three replicates per reach. Algal material was placed on a GF/C filter, sprinkled with $MgCO_3$, and then wrapped in aluminum foil, kept

on ice until return to the field office and then frozen. Triplicate samples (two additional replicates per transect) were taken at the Blindman River site for QA/QC purposes.

Epilithic algae for taxonomic analysis were also obtained using the template method, but in this case scrapings (4 cm^2 /scraping) from nine rocks (three per transect) were combined to form one composite sample. The sample was preserved with Lugol's solution and five drops of formaldehyde. Additional samples (three replicates, collected as described) were obtained from the Blindman River to describe variability in taxonomic data.

3.2.4 Phytoplankton

Water was collected from five cross channel points along the lower (T1) transect and pooled in a carboy. The sample was well mixed and poured off into 1L dark Nalgene containers for Chl-*a* analysis and 100 mL phytoplankton jars. Chl-*a* samples were filtered on GF/C filters in the laboratory; MgCO3 was sprinkled on the filter before freezing.

Phytoplankton samples for taxonomic analysis were preserved in the field with Lugol's solution and a few drops of formaldehyde. Two additional samples were poured off from cross sectional composite samples collected sequentially (over a period of approximately half an hour) at the Blindman River site to assess variability over time.

3.2.5 Sediment

One composite sediment sample per site was collected from depositional areas along the three transects, using the 'spoon method' as described in Alberta Environment (2006). These composite samples, destined for particle size and nutrient analyses, were stored in plastic bags and kept cool until delivery to the analytical laboratory.

3.3 Sample Processing Methods

3.3.1 Benthic Invertebrate Samples

The zoobenthic samples were washed over a 2, and a 0.210 mm sieve. The coarse fraction was sorted in its entirety; the material washed onto the fine sieve was sub-sampled using a Marchant Box (Marchant 1989). A minimum of 500 organisms were sorted, or at least three of the 100 cells in the Marchant Box were processed. This was needed to obtain a minimum level of precision deemed necessary for the (sub)sampling invertebrates (see Elliott 1977, Wrona et al. 1982). All invertebrates were sorted under a dissecting microscope (magnification range 6 to 50X).

Specimens were identified to genus or species where possible, according to Edmunds *et al.* (1976), Wiggins (1977), Merritt and Cummins (1996), Clifford (1991), Thorp and Covich (2001), and others using the most current taxonomic designations available (See Taxonomic References)

Benthic Invertebrate taxonomic analyses are presented in Appendix 2.

3.3.2 Epilithic and Plankton Algal Taxonomy, and Chlorophyll-a Analyses

Chlorophyll-*a* was determined fluorometrically after acetone extraction at the Analytical Chemistry Laboratory, Alberta Research Council, Vegreville. Phaeophytin-*a*, a degradation product of chlorophyll was measured in epilithic samples. Results are reported as mg/m^2 for epilithic samples and mg/m^3 for plankton samples.

Non-diatoms (soft algae) and diatoms were analyzed separately. Depending on their concentration, non-diatoms samples were diluted first. To determine the appropriate dilution, the original samples were screened to assess the densities of algae and non-algal matter (debris and particulate matter). Aliquots of the appropriately diluted samples were allowed to settle overnight in sedimentation chambers following Utermöhl's procedure described in Lund *et al.* (1958). Algal units were counted from a minimum of four transects on a Zeiss Axiovert 40 CFL inverted microscope. Counting units were individual cells, filaments, or colonies depending on the organization of the algae. Both diatoms and non-diatoms were counted. For soft algae, between 250 and 300 units were counted at 500X magnification; a number transects were scanned at 250X for larger algae. For diatoms, a minimum of 250 was set as the target. At this stage, diatoms were not identified to species or genus, but recorded as "diatoms", and were later identified to species from prepared slides.

Preparation of diatom slides consisted of digesting sub-samples using concentrated nitric acid and hydrogen peroxide and washing several times (by centrifuging) with distilled water. A few drops of the diatom slurry were placed on a cover slip and allowed to evaporate overnight. Once dry, the diatoms were mounted in Naphrax and identified using 1000 to 1500 X magnifications (under oil immersion) on a Zeiss Axioskop 40 compound microscope. A minimum of 500 diatom frustules were counted on each slide. The diatom counts on the slides were converted to density based on the number of transects covered during the fresh (Utermöhl) counts.

Biomass was calculated from recorded abundance and specific biovolume estimates, based on geometric shapes (Rott 1981), assuming a specific gravity of one. The biovolume (mm^3/m^3 fresh weight) of each species was estimated from the average dimensions of 10 to 15 individuals. The biovolumes of colonial taxa were based on the number of individuals in a colony. All calculations for cell concentration ($units/cm^2$) and biomass ($\mu g/cm^2$) were performed with Hamilton's (1990) computer program.

Taxonomic identifications of soft algae were based primarily on Anton and Duthie (1981), Entwisle et al. (2007), Findlay and Kling (1976), Huber-Pestalozzi (1961, 1972, 1982, 1983), Tikkanen (1986), Prescott (1982), Whitford and Schumacher (1984), Starmach (1985), Komarek & Anagnostidis (1998, 2005), and Wehr and Sheath (2003). Diatom identifications were based primarily on the following texts and supplemented with other publications: Krammer and Lange-Bertalot (1986, 1988, 1991a,b), Reavie and Smol (1998), Cumming *et al.* (1995), Bahls (2004), Camburn and Charles (2000), Fallu *et al.* (2000), Patrick and Reimer (1966, 1975), Siver and Kling (1997), and Siver *et al.* (2005).

Results of epilithic and plankton algal community data are shown in Appendix 3 and 4, respectively.

3.3.3 Sediment Chemistry

Particle size, organic carbon, total nitrogen (as TKN) and total phosphorus were analyzed in sediments collected at each site. Method descriptions are outlined below.

Total Phosphorus: the sediment sample is digested with sulfuric acid, potassium sulphate and a mercury catalyst at 360°C. All phosphorus species are converted to phosphate which is determined colorimetrically in an automated system by the molybdate-antimony tartrate-ascorbic acid method.

Total Kjeldahl Nitrogen: sediment sample is digested with sulfuric acid, potassium sulphate and a mercury catalyst at 360°C. Organic nitrogen is converted to ammonia, which is determined colorimetrically in an automated system by the phenate method.

Organic Carbon in sediments is determined by the difference between total carbon and inorganic carbon. Total carbon in sediments is obtained by placing a known amount of sample in a crucible and combusting the sample at 950°C. The carbon dioxide formed is measured in an infrared cell. Inorganic carbon in sediment samples is obtained by acidifying a known amount of sample with excess sulphuric acid. The evolved CO_2 is trapped in sodium hydroxide. The partial alkalinity of samples is compared to $CaCO_3$ standards to determine total carbonate and inorganic carbon.

Particle size distribution in sediments is measured using the hydrometer method and is based on M.R. Carter (1993) as described in Soils Sampling and methods of Analysis, 507:509. Lewis Publishers.

3.4 Data Analysis

This small dataset did not lend itself to statistical analyses (e.g., comparison among sites). Therefore, evaluation of results relied primarily on visual appraisal of graphs and tables. Simple metrics were calculated; these included taxonomic diversity (i.e., number of major taxonomic groups, genera, or individual taxa) and absolute and proportional (percent) abundance and biomass (algae, only) at various taxonomic levels. An extensive exploration of merits of a broad range of 'metrics' was not justified here because of the limited data set.

However, the applicability of recent work by Potapova and Charles (2007), involving the development of a nutrient preference index for diatoms, was tested with the diatom data from this pilot study. The authors compiled an indicator species list by defining the nutrient preference range for riverine diatom species in the United States based on species distribution and nutrient data. Data used in this process are those from the U.S. Geological Survey National Water Quality Assessment program. Species which had the highest mean relative abundance and frequency of occurrence at $TP \leq 10\ \mu L^{-1}$ were designated as 'low TP or LP', those with $TP \geq 100\ \mu L^{-1}$ as 'high TP or HP', those with

$TN \leq 0.2\ mgL^{-1}$ were designated as 'low TN or LN', those with $TP \geq 3\ mgL^{-1}$ as 'high TN or HN'. A high index value indicates that species which thrive under high nutrient conditions prevail, and *vice versa*.

Indices for total phosphorus (P-preference index) and total nitrogen (N-preference index) indicators were calculated as:

$$\text{P-Preference index} = \frac{10HP}{HP+LP}$$

$$\text{N- Preference index} = \frac{10HN}{HN+LN}$$

The indices for our stream data were calculated using species abundance data. In addition, absolute and relative abundance of species with high, low, and unclassified nutrient preferences were graphed. 'Unclassified' species were those which did not appear or did not receive a rating in Potapova and Charles (2007).

4.0 RESULTS AND DISCUSSION

4.1 General Site Description

As mentioned earlier (Table 1), the three watersheds are located in different ecoregions and they drain lands that are farmed with different intensity. In part as a result of these different features, there were some important site-specific differences which would be expected to influence biological communities.

The Rose Creek site had mostly erosional substrate (cobble, gravel) with small depositional patches (sand and fines); at the time of sampling there was measurable flow (Appendix 1). The Blindman River held both types of habitat, although depositional substrate was dominant at the sampling site. There was some flow at the site, but it was not measurable. The Strawberry Creek site was dominated by depositional substrates and there was no flow at the time of sampling.

At the time of sampling water was well oxygenated, alkaline, and conductivity ranged from 316 $\mu S.cm^{-1}$ in Rose Creek to 611 $\mu S.cm^{-1}$ in Strawberry Creek. Macrophytes were present at all sites, but they were abundant (25-50% coverage) at only one transect on Strawberry Creek. Bank stability was considerably affected by uncontrolled access of cattle to the Blindman River. Livestock trails were visible, but to a much lesser extent at the Rose Creek site. Strawberry Creek had unstable banks, including some steep banks with no vegetation and erodable soils; there was no evidence of cattle activity at this site.

Riparian cover at Rose Creek was comprised of sedges, shrubs, deciduous and coniferous trees, and a relatively small amount of bare soil. At the Blindman River site grasses, sedges and shrubs dominated along with bare soil especially where cattle accessed the stream. Strawberry Creek had a mix of grass, sedges and shrubs with some deciduous trees. Terrestrial canopy cover over the wetted area was low at all sites. A beaver dam was present about 100 m upstream of the upper transect on the Blindman River, and about 1 km downstream of the lower transect on Strawberry Creek. No beaver dams were observed in the immediate vicinity of the Rose Creek site.

4.2 Practical Considerations about the Pilot Sampling

Following are general observations regarding time commitment, training requirement, and suitability/practicality of sampling techniques.

It took each of three staff approximately 6, 7 and 9 hours to perform field data and sample collections at Rose Cr., Strawberry Cr., and the Blindman River, respectively. Time estimates for this pilot study are probably in excess of what would be required if sampling was part of routine monitoring. Note that the Blindman River, which took the greatest amount of time, involved much additional sampling (triplicate sampling of benthic invertebrates and algae).

Field measurements such as GPS readings, hydrometric measurements, and multi-probe readings require familiarity with equipment and procedures, but was otherwise easy to

standardize. The documentation of the various reach and bank characteristics was somewhat more difficult to standardize because it involves visual observations and qualitative measures.

Collection of benthic invertebrates with kick nets was the most practical approach considering the wide range of variability in depth, substrate type and flow conditions expected in streams across Alberta. Both kick nets (210 and 400 μm mesh size) performed well in Rose Creek which had coarse substrates. Clogging of the nets with fines was an issue in the Blindman River and Strawberry Creek which are more depositional in nature. Kick nets only allow qualitative sampling (i.e., not quantitative). Fixed-time sampling (3 minutes per sample in this pilot study) is one way of standardizing the samples. However, additional factors need to be standardized among sites, samplers, and over time to achieve reasonably consistent sampling. These include the intensity of kicking, the velocity with which the net is swept back and forth, and the sampler's travel speed. Staff training and reliance on experienced staff are critical in the collection of samples that can be compared over time and among sites.

Suitable rocks for epilithic algae sampling were eventually found at all 3 stream sites. However, the time involved in finding rocks was greatest at the Strawberry Creek site which was more depositional in nature than the two other sites. Alternative sampling approaches are needed to sample sandy or muddy sites devoid of rocks. The use of a small (2.5 cm diameter) core is currently being tested to sample such fine-grained substrates.

Sampling of water quality, including phytoplankton and sediments was straightforward at all sites.

If sampling of AEH indicators in small streams were to become part of a regular program, staff training and consistent involvement of experienced staff would be critical in achieving consistency in site assessments and acquisition of standardized samples. Based on the experience of this pilot study it is estimated that sampling of water, sediments, benthic invertebrates (one kick net), epilithic algae and conducting the field measurements would require a minimum of 2 to 3 hours from a well-trained crew of three.

4.3 Sediment Analyses

Sediment analyses are summarized in Table 2. Particle size distribution illustrates some of the habitat differences described earlier. Sediment collected from Rose Creek was mostly sandy, whereas sediment from the other two sites also contained a substantial amount of silt and clay. Organic carbon was low at all sites.

Table 2 Sediment particle size and nutrient levels

	Rose Creek	Blindman River	Strawberry Creek
Sand %	98	66	73
Silt %	<1	17	13
Clay %	2	17	15
Organic Carbon %	<0.8	<0.8	0.8
Inorganic Carbon %	0.4	1.8	1.6
Total Carbon %	0.6	2.3	2.4
Sediment TKN mg/kg	259	1860	939
Sediment TP mg/kg	504	842	541

Consistent with the substrate type and level of agricultural intensity, Rose Creek had the lowest levels of total phosphorus and nitrogen. Blindman River sediments had the highest levels of nutrients, along with the highest percentage of silt and clay.

4.4 Benthic Invertebrates

Comparison of sites

Benthic invertebrates were abundant and diverse in the three streams (Appendix 2). In total, 128 taxa belonging to a wide variety of invertebrate taxonomic groups were recorded (e.g., Turbellaria, Nematoda, Oligochaeta, Hirudinea, Cladocera, Copepoda, Ostracoda, Amphipoda, Ephemeroptera, Plecoptera, Trichoptera, Diptera, Hemiptera, Coleoptera, Odonata, Mollusca, and Acari). Based on collections with both nets, the number of invertebrates was lower in Rose Creek than in Strawberry Creek and the Blindman River, in particular. However, taxonomic diversity was greater in Rose Creek and the Blindman River than in Strawberry Creek (Figure 2 a, b, and e); this trend is likely related to differences in substrate sampled in the three streams (Appendix 1).

The invertebrates collected with the 210 µm net at the Rose Creek site were dominated numerically by Chironomidae, Trichoptera, Ephemeroptera and Oligochaeta; other groups such as Plecoptera and small crustaceans (Cladocera, Copepoda, Ostracoda) were also well represented (Figure 2 d and e). Ephemeroptera, Plecoptera, and Trichoptera, often referred to as "EPT" are, for the most part, typical inhabitants of erosional substrates, and relatively good water quality, and they were most abundant and diverse in Rose Creek (Figure 2 c). Another typical inhabitant of hard bottom erosional substrates only encountered in Rose Creek was the mollusc *Ferrissia rivularis* (Appendix 2). Despite the dominance of erosional species, some typical inhabitants of depositional substrates included the burrowing mayfly *Ephemera* and small numbers of *Ilyocryptus sordidus*, a benthic cladoceran with special adaptations (haemoglobin) to low dissolved oxygen levels (Appendix 2).

The fauna from the Blindman River and Strawberry Creek site was dominated by small crustaceans, Oligochaeta, and Chironomidae. Although some of the crustaceans are planktonic (e.g., *Daphnia, Chydorus*, cyclopoid copepods), the typically benthic *Ilyocryptus sordidus* was abundant at these sites. Amphipoda (*Hyallella azteca* and

Gammarus lacustris) were fairly abundant in the Blindman River, but they occurred in low numbers in Strawberry Creek. Ephemeroptera and Trichoptera were present at the Blindman River and Strawberry Creek sites although they were less diverse and abundant than in Rose Creek. Leptophlebiidae were the only Trichoptera found at the Strawberry Creek site. No Plecoptera were found in the Blindman River or Strawberry Creek.

The fauna from Rose Creek was indicative of a well oxygenated, erosional habitat with moderate nutrient levels; whereas the fauna from the Blindman River site suggested a mixed habitat, potentially with areas of low dissolved oxygen and generally with higher nutrient levels. Substrate, flow and dissolved oxygen conditions appeared to be even more restrictive in Strawberry Creek.

Although the variability in the number of benthic invertebrates in the Blindman River replicates was large, particularly in the 210 μm mesh kick samples, the total number of taxonomic groups per sample and the relative contribution of major taxonomic groups to total numbers were less variable (Figure 2). This is relevant as it suggests that the manner in which kick samples were collected provided a repeatable indication of the invertebrate community composition.

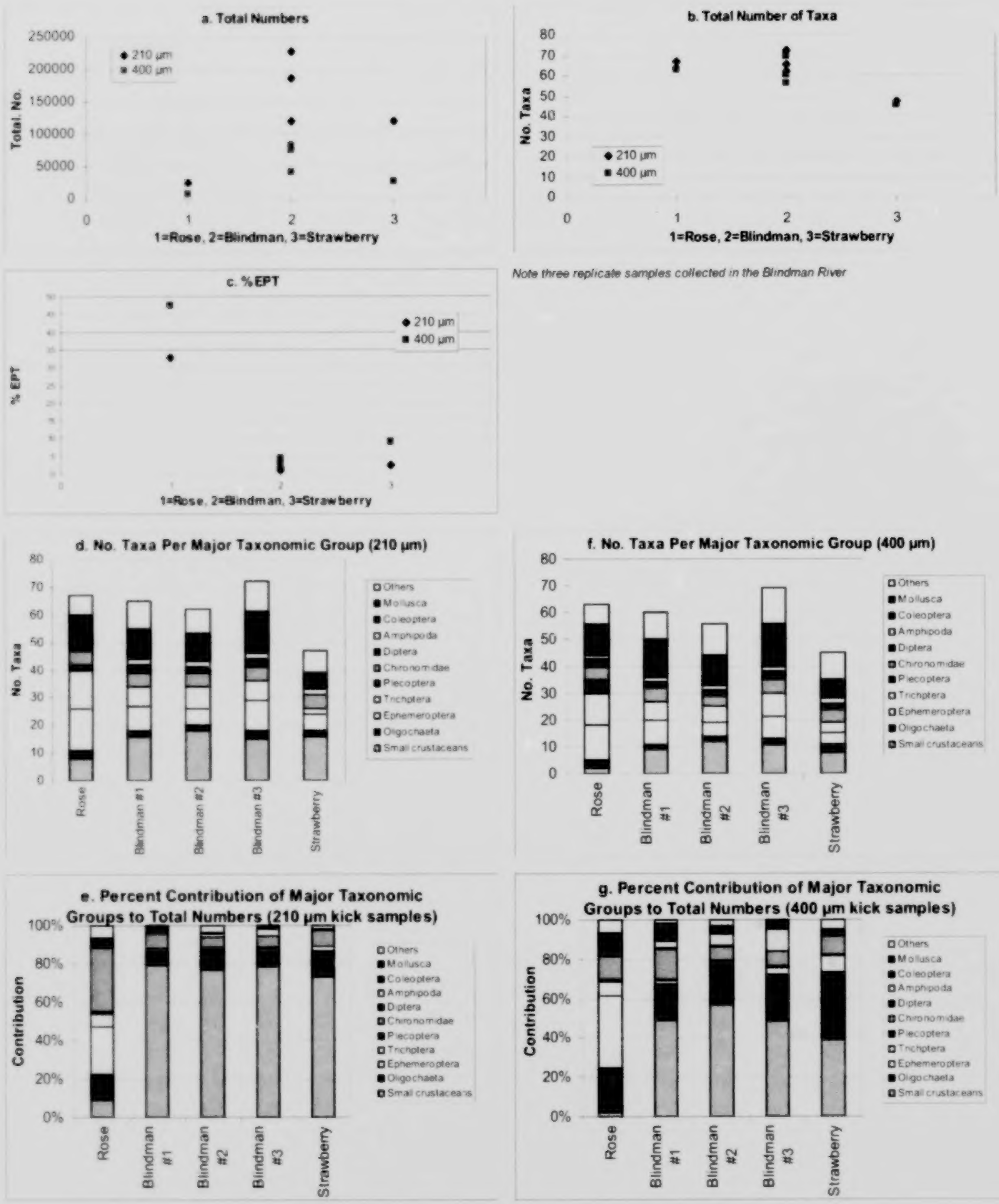

Figure 2 Benthic invertebrate data for three agricultural streams

Comparison of samples collected with the 210 and 400 µm kick samples
Differences among sites were consistent in samples collected with the 210 or 400 µm kick net. However, as could be expected, total counts in the 210 µm nets were consistently higher, or much higher, than in the corresponding 400 µm. The difference in taxonomic diversity between nets was not as pronounced, but samples collected with the finer net had 2 to 6 additional species, compared to those collected with the coarse net (Figure 2 a and b, Appendix 2).

Overall abundance and taxonomic diversity were lower in 400 µm kick samples, but not all taxonomic groups were affected in the same way (Appendix 2):

- Many of the small crustaceans are small enough that they could pass through the 400 µm mesh. As a result their number and diversity were considerably lower in the coarse kick net samples. With the exception of *Simnocephalus*, a rather large cladoceran, small crustaceans would have been missed altogether at the Rose Creek site with the 400 µm mesh kick sampler.
- Interestingly, some molluscs (e.g., Valvatidae, *Pisidium* and Sphaeridae), were more numerous in the 400 than 210 µm kick samples.
- Furthermore, some invertebrates were encountered only in the 400 µm kick samples. These include the caddis flies *Argaylea* (Blindman), and *Mystacides* and *Amphicosmoecus* (Rose Creek) and the stoneflies *Pteronarcys* and Perlodidae (Rose Creek).

The differences in results between the two nets are likely due to the greater filtering capacity of the coarse net. The fine net clogs up faster and once this happens organisms can escape actively, or they can easily be washed away with water that does not pass through the net anymore.

Considering that general faunal differences among sites remained consistent regardless of the net used (i.e., interpretation of the data would have been similar), there are some advantages in using the coarse net. These include dealing with samples that have somewhat fewer, but larger organisms and the fact that the response to environmental disturbance of many larger organisms is often better understood that that of small crustaceans.

In a comparison of Bow River benthic invertebrate samples collected with Neill cylinder and the same two kick nets as in this study, Saffran and Anderson (2009) also noted the similarity in general longitudinal patterns obtained regardless of sampler, or mesh size used. However, because there is a historical invertebrate database that relied on Neill samples, and also because of advantages offered by routinely replicated Neill cylinder samples in statistical significance testing, recommendations were made to continue using Neill samplers in large provincial rivers.

There is no historical database for benthic invertebrates in agricultural streams and, hence, considering their apparent advantages, the use of 400µm kick nets, could be recommended in future sampling of small streams. Substrate can vary considerably in agricultural streams and kick nets could be used in erosional or depositional type substrates where Ekman grabs and Neill cylinders, respectively, would not be suitable.

4.5 Epilithic Algae

Epilithic algae formed diverse species associations at the three sites. Diatoms (Bacillariophyceae) were the most diverse group with a total record of 85 different taxa belonging to 25 genera. Chlorophytes (Chlorophyceae) with 27 different taxa (12 genera) were the second most diverse, followed by Cyanobacteria with 15 different taxa (11 genera). Xanthophyceae and Dinophyceae were minor groups in terms of taxonomic diversity (one taxon each), abundance and biomass (Figure 3, Appendix 3).

Cell counts and biomass were greatest in Strawberry Creek (Figure 4 a, b) and taxonomic diversity was lowest in Rose Creek (Figure 4 c). Diatoms and Cyanobacteria contributed most to cell counts and biomass, but the chlorophytes *Spirogyra* sp. and *Cladophora* sp. were important biomass contributors in one of the replicates taken at the Blindman River site and at the Strawberry Creek site, respectively (Figure 3 a, b, d, Appendix 3). Dominant diatoms in terms of biomass contribution were *Cocconeis pediculus*, *Cocconeis placentula* (Rose Creek), *Cocconeis placentuala* (Blindman River), *Mastogloia smithii* and *Rhopalodia gibba* (Strawberry Creek). *Gloeotrichia* (Cyanobacteria) and *Cladophora sp.* and *Pediastrum boryanum* (Chlorophyceae) dominated the biomass at Strawberry Creek (Appendix 3).

Replicates (each consisting of scraping from 3 rocks taken from each of the 3 transects) taken at the Blindman River site show that there are differences in the diversity, cell counts and calculated biomass (Figure 3), although the same major groups account for most of the abundance and diversity (Figure 4). The largest differences among the three replicates occur in biomass estimates and are due to the importance of one Chlorophyceae taxon (*Spirogyra* sp.) in one of the replicates and not the other (Figure 3 d, Appendix 3). These differences are indicative of natural spatial heterogeneity, and QA/QC samples need to be incorporated in further stream sampling to verify how representative composite samples (3 rocks from each of 3 transects) are of the sampled stream reach.

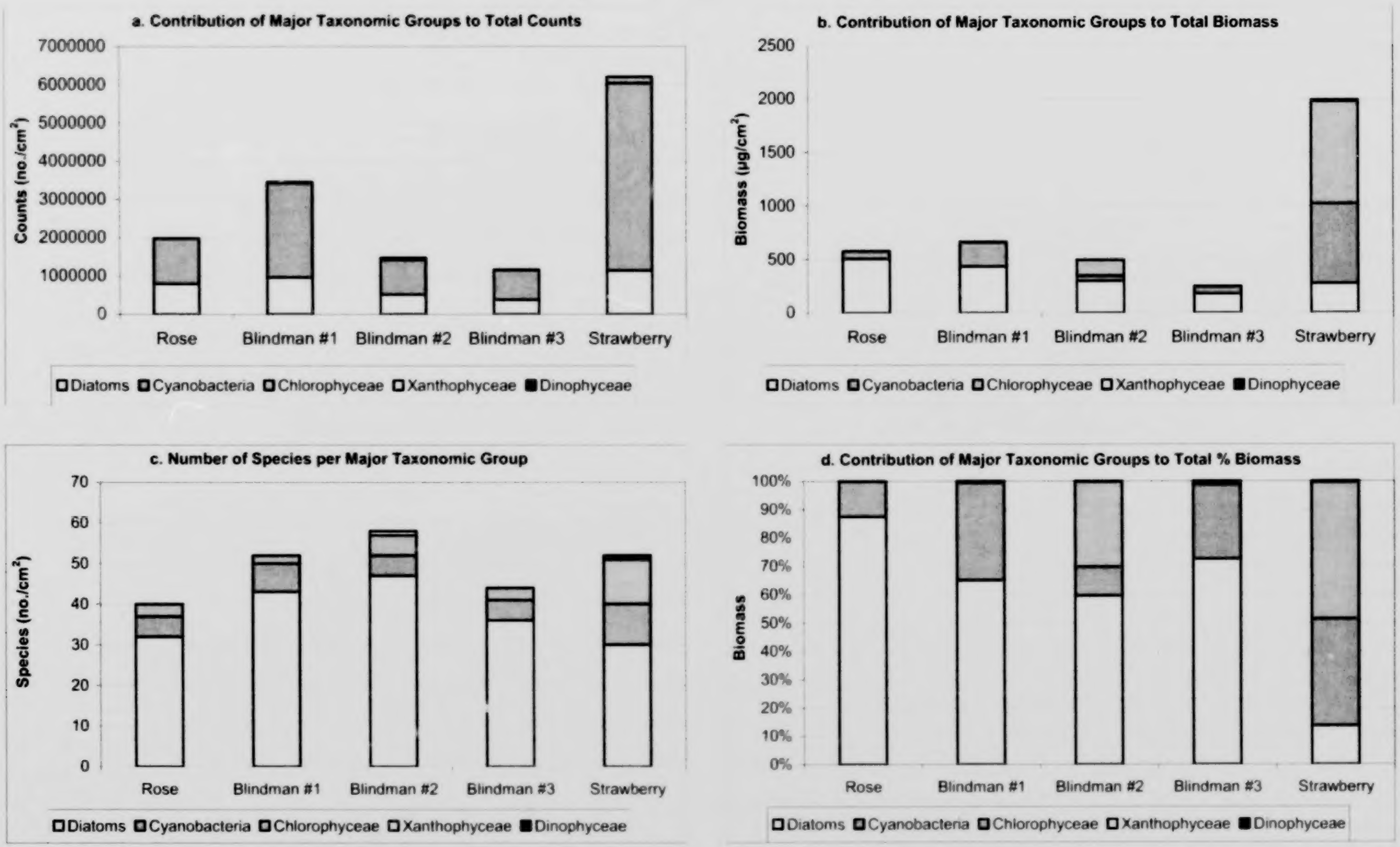

Figure 3 **Epilithic algae: major taxonomic groups in agricultural streams**

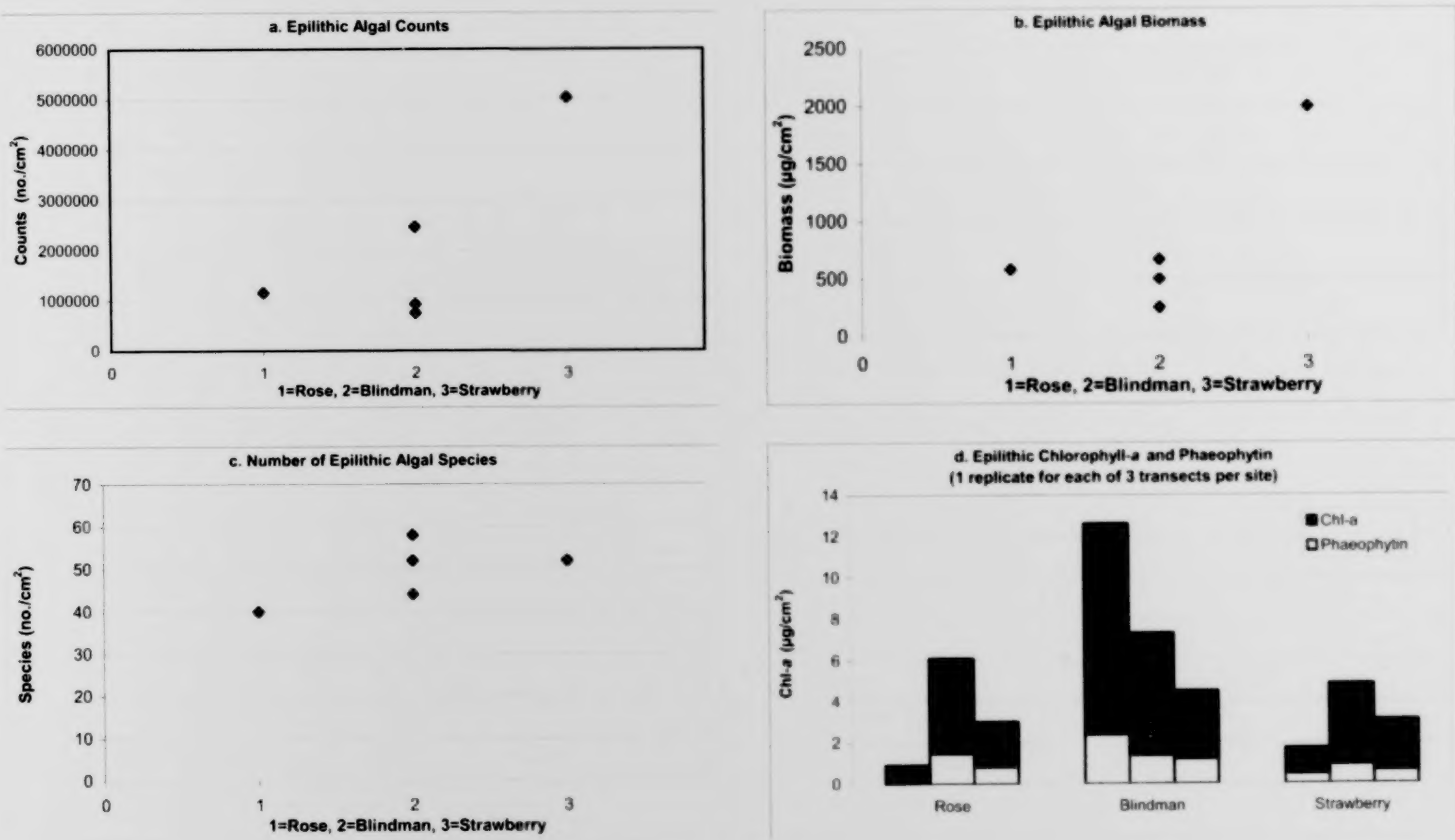

Figure 4 Epilithic algal counts, biomass, chlorophyll-a and number of species in agricultural streams

Chlorophyll levels varied substantially among the three replicate samples collected at each site and this illustrates the variability among transects (Figure 4d). In contrast with biomass estimates based on cell volumes (Figure 4 b), chlorophyll-*a* levels, which also are an indicator of biomass, were highest at the Blindman site and they were rather similar between Rose and Strawberry creeks (Figure 4 d). Based on biomass calculated from cell volumes, Strawberry Creek had the highest biomass, but not based on Chlorophyll-a. The difference may be due to the dominance of *Gloeotrichia* at the site. *Gloeotrichia* forms mucilaginous colonies which can become very abundant and coat the substrate with a thick mucilaginous film. The chlorophyll-*a* content, however, may be rather low as phycobilins, rather than chlorophyll-*a*, tend to be the dominant photosynthetic pigment in cyanobacteria. Hence, taxonomic information is an insightful complement to chlorophyll-*a* measurements and contributes to a better understanding of biomass patterns in epilithic communities.

The relationship between diatom distribution and water quality is better documented than that of soft bodied algae (Potapova 2005), and diatoms are widely used to monitor river conditions in the United States and Europe (Potapova and Charles 2007, Tison et al. 2005).

Nutrient preference classes and N and P preference indices derived by Potapova and Charles (2007) were applied, to determine if diatom metrics could be used to differentiate among agricultural streams (Figure 5). This is one way in which relationships between nutrient levels and diatom species composition can be established in agricultural streams. Rose Creek had a lower index value for P (Figure 5 a) and N (Figure 5b) than the Blindman River and Strawberry Creek. In Strawberry Creek, and especially the Blindman River, species with high nutrient preference were considerably more abundant than species with low nutrient preference (Figure 5 c to d). In Rose Creek, numeric contributions of diatoms with high and low nutrient preferences were equivalent.

Total nutrient concentrations in our agricultural streams are rather high compared to the threshold ranges defined by Potopova and Charles (2007) (Table 1). For TP and TN the three pilot streams would all fall in the high nutrient range. If dissolved nutrients were considered, Rose Creek would fit in an intermediate range for TDP, while the Blindman River and Strawberry Creek still fit in the 'high' range. All streams would fall in the intermediate range for dissolved nitrogen. The differences among sites in nutrient preferences of diatoms are consistent with the differences in nutrient levels observed in water and sediments. This suggests that diatoms may be potential indicators of the trophic status of agricultural streams.

As noted by Potapova and Charles (2007), metrics derived from diatom-nutrient relationships tend to be more useful when they are derived from, and employed in regional-scale studies rather than continental or intercontinental studies. As more epilithic algal taxonomy information is associated with water quality information, it will become possible to refine such metrics for Alberta.

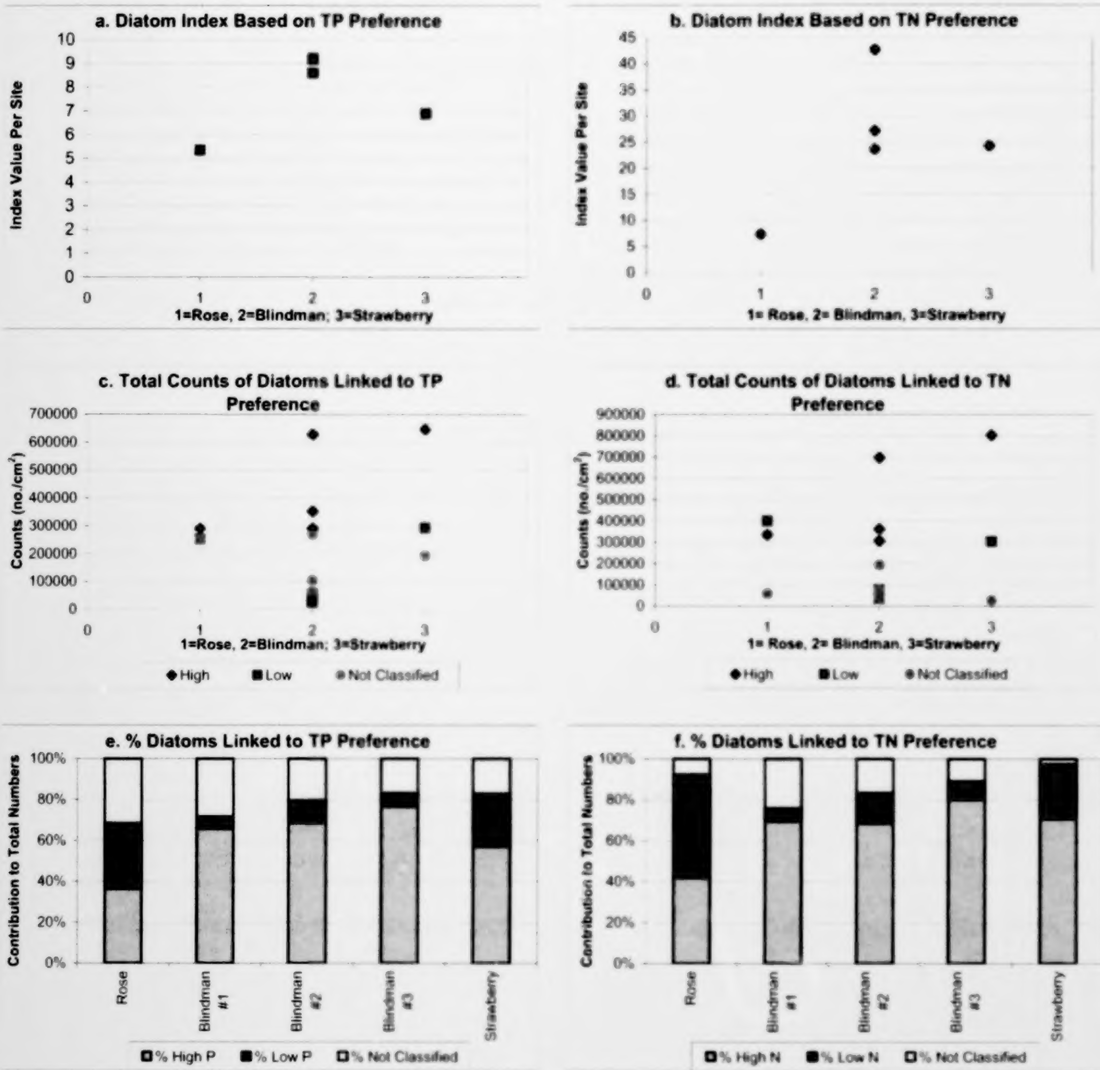

Figure 5 **Diatom metrics for monitoring eutrophication in agricultural streams (after Potapova and Charles, 2007)**

4.6 Phytoplankton

A total of 50 individual taxa, comprising 35 different genera were recorded in phytoplankton samples. These include Cyanobacteria (5 taxa, 5 genera), Chlorophyceae (16 taxa, 12 genera), Chrysophyceae (5 taxa, 3 genera), Cryptophyceae (8 taxa, 3 genera), Euglenophyceae (3 taxa, 3 genera), Dinophyceae (3 taxa, 1 genus), and Bacillariophyceae (Diatoms: 10 taxa, 9 genera) (Appendix 4). The algal classes Chrysophyceae, Cryptophyceae and Euglenophyceae which occurred in plankton were not found in the epilithic algal samples (Appendix 3).

The three replicates collected sequentially at the lower transect in the Blindman River showed a lot of variability in terms of cell counts, biomass, taxonomic diversity (taxa and genera) and specific taxonomic compositions (Figures 6 and 7). The degree of variability observed at the Blindman site encompassed the range of variability observed at the three sites. On average, cell counts, biomass and diversity were slightly higher at the Blindman site, but chlorophyll-a content (single sample) was noticeably higher (Figure 6). The high degree of variability observed in phytoplankton replicates from the Blindman site may be an indication of heterogeneity in phytoplankton communities of small streams. If this is the case, composite samples taken along the sampling reach would likely be better indicators of site conditions than single grab samples.

Cryptophytes and Euglenophytes were numerically abundant at all sites (Figure 7). Chlorophytes contributed most to the biomass and diversity of Rose Creek, and they were diverse and important contributors to the biomass in one of the Blindman replicates, but not the others. Chlorophytes were poorly represented at the Strawberry Creek site where Cyanobacteria were more abundant and diverse and contributed more to the biomass than at any other site. Cyanobacteria were not recorded in the phytoplankton from Rose Creek. Although diatoms were present at all sites, their abundance, biomass and diversity was rather low, especially compared to their importance in epilithic algal samples.

Individual species which were important biomass contributors at Rose Creek were *Mougeotia* (Chlorophyceae) and *Cocconeis* (Bacillariophyceae). *Cryptomonas marsonii* and *Rhodomonas minuta* (Cryptophyceae) and *Euglena minuta* were important at Strawberry Creek. At the Blindman River site, *Chlamidomonas* (Chlorophyceae), *Cryptomonas erosa*, *Cryptomonas reflexa* and *Rhodomonas minuta* (Cryptophyceae) and *Euglena minuta* (Euglenophyta) contributed substantially to the biomass of each of the three replicates. Other species were important in only one or two of the Blindman River replicates (e.g., *Cocconeis*, *Cryptomonas erosa*, unidentified Chrysophytes, *Pediastrum boryanum*, and *Microspora*).

The diversity of diatoms in phytoplankton samples was far too low to attempt to calculate Potapova and Charles' nutrient indices, or to relate diatom nutrient preferences to trophic status.

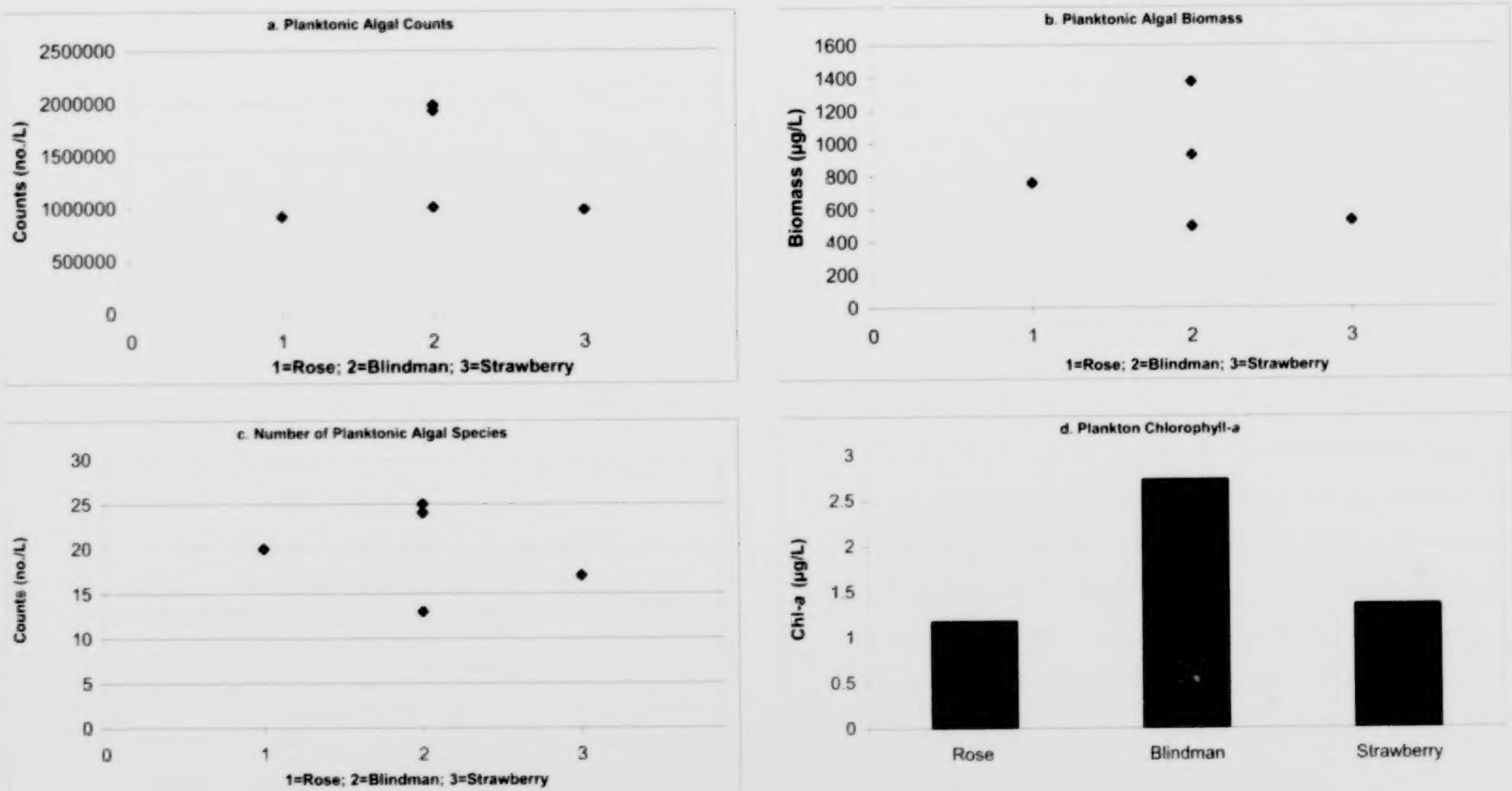

Figure 6 **Planktonic algal counts, biomass, chlorophyll-a, and number of species**

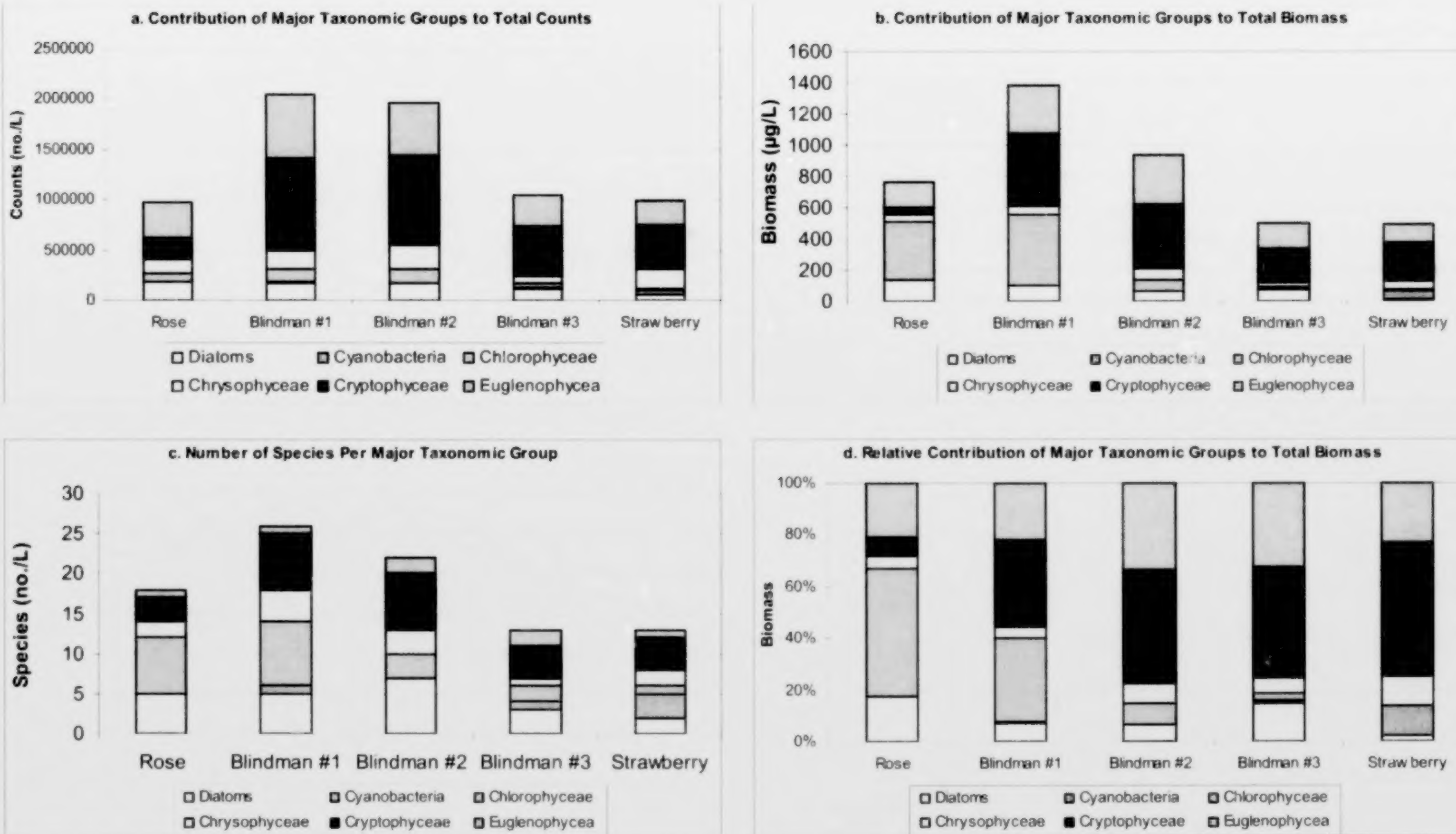

Figure 7 Planktonic algae: major taxonomic groups in agricultural streams

5.0 GENERAL DISCUSSION

5.1 Suitability and Practicality of Monitoring Techniques

The pilot study has illustrated the practicality of collecting biological communities and sediments from small Alberta streams.

- Kick net samples collected with a 400 µm mesh offer some advantages over those collected with the 210 µm and would be recommended for further sampling of small streams.
- Sediment and epilithic algal sampling procedures described in AENV (2006) were appropriate for agricultural streams. However, rocks suitable for epilithic algal sampling are often difficult to find in streams where depositional habitats prevail. The use of alternate sampling methods needs to be investigated further (e.g., "mini core" sampler).
- A critical goal of future sampling should be to ensure that samples and field information are collected in a consistent manner by experienced staff so that data are comparable over time and among sites. Although this is a general requirement of any sampling program, it applies particularly to AEH-related sampling components that are qualitative or semi-quantitative, or that rely, to some extent, on value judgement (e.g., benthic invertebrate kick samples, field observations of bank and reach characteristics). Sampling protocols need to be developed and included in the field manual, and staff training ensured.

5.2 Selection of Potential Indicators of Health

Benthic invertebrate and algal communities were diverse and abundant and offer good potential for further monitoring, along with water and sediment quality. Involvement of trained field staff and diverse scientific expertise through the full monitoring, evaluation, and reporting process is important. This expertise should complement and build on existing information when appropriate. Examples of existing information for benthic invertebrate and algal groups include:

- Benthic invertebrates have been used widely to document the ecological "health" or "integrity" of surface waters and they have been used extensively in biomonitoring programs (e.g., Klemm et al. 2003, Wright et al. 1995, Sylvestre et al. 2005). Ecological requirements and responses to various forms of disturbance, such as nutrient enrichment and toxicity, are relatively well understood (e.g., Hilsenhoff 1987, 1988, Mandaville, 2002, Carlisle et al. 2007). Biological criteria have been developed for many states in the U.S. (e.g., Younos 2002). There is obvious benefit to including benthic invertebrates in future biological monitoring of small streams. The composition and abundance of aquatic communities, such as benthic invertebrates, integrate changes in the chemical and physical environment, unlike water quality samples which represent conditions at the time of sampling.
- In addition, algal growth on bottom substrates is a very useful measure of the influences of nutrient enrichment in streams. For example, diatoms have also been widely used to assess various stressors on water quality (e.g., NAWQA data

set used in Potapova and Charles 2005), species specific responses to nutrient enrichment, acidification, and discharge alterations have been documented and many indices have been developed to summarize responses to environmental changes (e.g., Soininen 2004,Potapova and Charles 2005, Tison et al 2005). Some researchers believe that diatoms are a more sensitive indicator to nutrient enrichment than benthic invertebrates (Steinberg and Schiefele 1988). The wealth of species-specific ecological information and the numeric and taxonomic dominance of diatoms in our epilithic algal samples, flags this group, in association with other epilithic algal species, as a potentially powerful biological indicator of eutrophication in small streams. This along with the relative ease to standardize collection and, compared to benthic invertebrates, more moderate sample processing cost makes epilithic algal communities a top candidate for further monitoring in small streams.

- In contrast, phytoplankton communities were the least diverse and most variable in terms of abundance and diversity. Diatoms were a relatively minor element of the phytoplankton associations, which were dominated by so-called "soft algae". Although soft algae are routinely monitored, their taxonomy and ecological requirements are not as well known (Potapova 2005). The phytoplankton species composition in our samples could be influenced, in part, by the time of year samples were collected (e.g., diatoms would likely be more abundant and diverse in spring e.g., Garnier et al. 1995). Overall phytoplankton in this pilot study appeared to yield less easily interpretable information than either benthic invertebrates or epilithic algae.

Information on sediment quality is needed to establish baseline conditions and further sampling of sediments in agricultural streams is recommended. There is a need to evaluate variables closely associated with agricultural activities, such as pesticides, pharmaceuticals and feed additives used in the livestock industry. In some cases, the evaluation of sediment quality data is hampered by the limited number of effects guidelines or thresholds to assess the significance of contaminant detections.

5.3 Considerations for Future AEH Monitoring of Agricultural Streams

Currently, one of the difficulties in assessing AEH in Alberta lies in defining the characteristics of 'healthy' aquatic ecosystems. Considerable progress has been made in the United States over the last 20 years to narrow down the concepts of biological "health" or 'integrity'. Following are key references extracted from Davis and Simon (1995):

- Biological integrity is defined as "…the ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to natural habitats of a region" (Karr and Dudley 1981).
- It is recognized that entirely natural or unimpaired habitats may no longer exist, but an estimate of expected biological integrity in surface waters can be based upon "least impacted conditions" or "reference conditions".
- Least impacted reference conditions form the basis for developing biological goals, or biological criteria.

The regional scale that is used to define biological criteria may vary among water body types, but ecoregions have been favoured for small to medium-sized streams by many researchers and agencies (e.g. Omernik 1995, Stoddard 2005, Tison 2005). Various stream types may exist within an ecoregion and in order to maximise the relevance of reference conditions, it is useful to classify streams based on natural hydrological features (e.g., stream order, drainage basin size, discharge patterns, contributing areas), and man-made features, in this case mostly related to non point sources (e.g., land use in watershed and along riparian areas, road crossings).

According to Hughes (1995), the number of reference sites needed to characterize reference conditions is a function of regional variability and size, the desired level of detectable change, resources and study objectives. Hughes proposed that 20 randomly selected sites from candidate reference sites in a given region provide a reasonable estimate of reference conditions. These selected sites could be subdivided in groups that account for different stream types.

The next and essential step is to acquire sufficient biological information from reference sites and match it with relevant chemical and physical characteristics of streams and watersheds. Such dataset would form the basis for developing biological criteria. Biocriteria may differ in nature, and, or numerical value depending on the ecoregion and type of stream (e.g., biocriteria based on Ephemeroptera, Plecoptera and Trichoptera may be relevant in Foothill stream, but not grassland streams where diversity and abundance of these groups is low).

Following are some key implications for the development of an AEH monitoring program on agricultural streams in Alberta.

- The AESA stream network offers a reasonable foundation in the sense that the 23 streams were selected from major ecoregions where agriculture is an important land use; streams were ranked according to agricultural intensity in their basins. There is a historical water quality database spanning a period of 8 to 13 years, depending on the stream. Surface water quality sampling was interrupted for all but 8 streams in 2008 and water quality sampling would need to resume.
- In order to define background conditions it would be necessary to expand the network. Considering that most of the network encompasses 4 ecoregions this could imply that a minimum of 80 (20 times 4) streams would need to be selected and monitored to establish reference conditions. In some instances it may be possible to select streams that are 'minimally' impacted, but in others, such as grassland streams in central Alberta, or irrigation canals, the goal may be simply to define current baseline conditions. Establishing background conditions can require several years. Rosenberg et al. (1999) sampled 219 sites over a three year period to establish reference conditions for benthic invertebrate monitoring in the Fraser River catchment in British Columbia.
- Frequency and intensity of monitoring would be high initially (e.g., many streams over a period of 2 to 3 years). Later on monitoring could be reduced to a selection of representative streams (e.g., the established AESA network, every 5 years). Periodic validation of a selection of reference sites would be useful to account for temporal variability.

- Timing of sampling would be particularly critical in ephemeral streams of grassland and Parkland regions where late spring may be the only time with flowing water and established biological communities. Sampling in Foothills and Boreal plain streams could likely be postponed to early summer.

Although the financial commitment to such monitoring program is large, it is one of the realities of meaningful monitoring and reporting on aquatic ecosystem health. In this case, strong baseline information would be established and biocriteria could be developed to report periodically on aquatic ecosystem health of agricultural streams.

It is expected that the value of biomonitoring of agricultural streams would extend well beyond periodic reporting on aquatic ecosystem health of these streams.

- Establishing reference conditions for a variety of streams would be very helpful to assess effects of other land uses (e.g., forestry or urban development).
- Another major application of biomonitoring information could be the assessment of the effectiveness of beneficial management practices, including riparian conditions, on aquatic ecosystem health (e.g., if nutrient control measures on land are effective one would expect to see corresponding changes in epilithic algal and benthic invertebrate communities).
- As nutrient and diatom association datasets for Alberta streams and rivers are expanded, the possibility would exist to validate nutrient tolerance ranges (e.g., as defined by Potapova and Charles 2007) for the range of regional conditions in Alberta, thereby refining the value of diatoms in the assessment of stream eutrophication in Alberta.
- Preference ranges for other species groups could also be investigated with associated data sets (e.g., Carlisle et al. 2007 investigated the influence of water quality on benthic invertebrate distribution).

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Appendix 1 Summary of field observations

River/Creek		Rose Creek at Alderflats	Blindman River near Blufton	Strawberry Creek at mouth
Site Number		AB05DE0010	AB05CC0479	AB05DF0020
Date		30-Aug-06	5-Sep-06	31-Aug-06
time on site	start (MST)	11:45	10:45	10:15
	end (MST)	17:30	18:00	17:30
In-stream measurements and observations				
GPS readings and reach delineation	Reach delineation Transect 1 (d/s)- T1	0 m NA NA	0m N52° 45' 18.7" W114° 17' 04.4"	NA N53° 18' 40.0" W114° 03' 12.5"
	Reach delineation Transect 2 (middle) - T2	51 m NA NA	80 m N52° 45' 21.2" W114° 17' 06.4"	NA N53° 18' 39.9" W114° 03' 15.7"
	Reach delineation Transect 3 (u/s) - T3	114 m N52° 55' 48.5" W115° 00' 37.4"	120 m N52° 45' 22.7" W114° 17' 06.9"	NA N53° 18' 39.8" W114° 03' 18.6"
	GPS Flow gauging	N52° 55' 48.5" W115° 00' 37.4"	see transects see transects	attempted at all transects
Hydrometric Data	Wetted width (m)	15.0	T1: 12.9; T2: 18.6; T3:14.2	T1:18m, T2: 12m;T3 24.7m
	Bank full width (m)	NA	T1: 17.5; T2: 21.5; T3:19.7	NA
	Depth (m)	0.07 - 0.081	0.14 to 0.71	0.69 to 1.0m
	Mean Flow velocity (m/s)	0.081	<0.014 (or <1 rev/min)	<0.014 (or <1 rev/min)
	Discharge (m^3/s)	0.430	not measureable	not measureable
Water Quality readings @ T1				
DO (mg/L)	Right bank	9.16	9.22	8.38
	Mid-right	9.11	9.27	8.3
	Centre	9.34	9.44	8.51
	Mid-left	9.32	9.32	8.71
	Left Bank	9.43	9.45	9.62
%DO saturation	Right bank	101.3	102.6	90.1
	Mid-right	100.7	103.2	89.4
	Centre	103.7	104.4	91.7
	Mid-left	103.4	103.4	93.8
	Left Bank	104.7	104.7	104.6
Conductivity (µS/cm)	Right bank	316	408	611
	Mid-right	316	409	611
	Centre	315	409	611
	Mid-left	316	410	611
	Left Bank	315	408	610

Appendix 1 Summary of field observations (con't)

River/Creek		Rose Creek at Alderflats	Blindman River near Blufton	Strawberry Creek at mouth
Site Number		AB05DE0010	AB05CC0479	AB05DF0020
Date		30-Aug-06	5-Sep-06	31-Aug-06
time on site	start (MST)	11:45	10:45	10:15
	end (MST)	17:30	18:00	17:30
pH	Right bank	8.36	8.22	8.45
	Mid-right	8.35	8.22	8.45
	Centre	8.4	8.18	8.46
	Mid-left	8.4	8.12	8.43
	Left Bank	8.42	8.15	8.53
Temperature (^{o}C)	Right bank	15.05	17.01	15.32
	Mid-right	15.03	16.91	15.31
	Centre	15.21	16.7	15.37
	Mid-left	15.22	16.73	15.46
	Left Bank	15.26	16.71	15.86
	Comments	RB in shade - LB in sun	LB in vegetation and some sun; RB in shade readings: 10:45 to 11:00MST	RB shaded and LB in sunshine at time of measurements (10:30 MST)
Stream Characteristics				
Stream Chracteristics	Riffle	-	-	-
	Run	X	X	-
	Pool	X	X	-
	Pool/Back eddy	-	-	X for T1,T2, and T3
Macrophyte Coverage	%	0 - 25	0-25	T1 and T2: 25-50; T3: 0-25
	Comments	Clasping pondweed along left bank aquatic mosses on large stable rocks Nostoc-like algae on some rocks	Clasping pond weed along T1and T2; filamentous algae along T2 and especially T3, some mosses, Nostoc-like algae and encrusted Cyanobacteria on rocks	Potamogeton, in shallow areas lots of Chara, buttercup and arrowhead weed
Substrate Composition (based on visual estimates)	% Bedrock >4000 mm	-	-	-
	% Boulders >250 - <4000 mm	all transects: 5	T1: 15; T2: 5; T3:10	-
	% Cobble >64 - <250 mm	T1:40, T2: 35, T3: 45	T1: 40; T2: 30; T3: 40	T1:15, T2:15, T3:80
	% Gravel >2 - <64 mm	T1:40, T2: 40, T3: 30	T1: 15: T2: 15; T3: 10	T1:5, T2:5, T3:10
	% Sand >0.06 - <2mm	T1: 10. T2 20, T3:20	T1:30; T2: 50: T3: 40	T1:80, T2:80, T3:10
	% Fines <0.06	some, esp. where cattle disturbance	incl. in % sand	included in "% sand"
	Comments	Most of the shore and stream bed on right bank disturbed by cattle, lots silts and clays		
Substrate Embeddedness	% of large substrates covered in fines	Moderate to high (50 to 75%) all transects	Low (20-50%) at T1 and T2; Moderate(51-75% at T3	High (>75) at T1 and T2, Low (25-50) at T3

Appendix 1 Summary of field observations (con't)

Bank Characteristics				
Stream bank stability	stable	LB - T 1, 2,and 3	T3: LB and RB	T1: LB; T2 and T3: RB
	Moderate	RB T1 and T3	T1: LB and RB	
	Low	RB - T2	T2: LB	T2:LB
	Unstable	-	T2: RB	T1: RB; T3: LB
	Comments	Decline in stability due to recent cattle trails; signs of old, overgrown trails on Left bank	Decline in stability due to uncontrolled access of cattle to the stream leading to extensive bank damage	Decline in stability appears related to geology (steep cliff at T3-LB) and Unstable soils at T1 and T2. No livestock activity in the immediate vicinity of this site
Bank Undercutting	None	LB - T1 and RB T 1,2,and 3	LB at T1 and T2	T1, T2, and T3
	Low	LB T2 and 3	LB at T3 and RB atT1, T2, and T3	-
	Moderate	-	-	-
	High	-	-	-
	Comments		Small beaver lodge built into LB at T3	-
Dominant riparian vegetation	% Bare Soil	LB: T1: 5, T2 and T3:0; RB:T1: 5, T2: 20, T3: 10	T2 - RB:10, LB: 30	T3 - RB: <5%, LB: 100%
	% Grass Sedge	LB: T1:80, T2 20, T3:15; RB: T1:15, T2:70, T3: 70	T2 - RB: 80, LB: 70; T3 - RB:60, LB:70	T3 - RB: 40%
	%Shrubs	LB: T1:5, T2: 70, T3 60; RB: T1:20, T2: 10, T3: 20	T3: LB and RB: 40	T3 - RB: 40%
	%Deciduous	LB: T1 and T2: 0, T3: 15; RB: T1:40, T2: 0, T3:10	-	T3 - RB: 10%
	% Coniferous	LB: all transects: 10; RB: T1 and T3:20, T2: 0	T2 - RB: 10, LB 1 large tree	-
Terrestrial Canopy Cover	Very low (0-5%)	all transects	T1, T2, and T3	T1, T2, and T3
	Low (6-25%)	-	-	-
	Moderate (25-50%)	-	-	-
	High (>50%	-	-	-

Notes:
T1, T2, T3: transect 1, 2 and 3
RB, LB: right bank, left bank
- not applicable
NA: no data
For further information on classification of measurements and measurements refer to Appendix ... (fieldsheets), ABMP protocols and CABIN protocols

Appendix 2 Benthic invertebrate community composition recorded in three agricultural streams in 2006

Sampling Dates: Blindman River at Bluffton: 5 September 2006; Rose Creek: 30 August 2006; Strawberry Creek at Mouth: 31 August 2006.
One sample is a composite of 3 one-minute kick samples taken along 3 transects. Individual one-minute kick samples for Blindman River were kept separate to evaluate variability among transects. Replicate samples (each consisting of 3 one-minute sub-samples) were also taken from the Blindman River.

Taxa	210 µm Mesh Size														
	Rose Creek	Blindman River													Strawberry Creek
		Replicate #1	1-1 (1 min)	1-2 (1 min)	1-3 (1 min)	Replicate #2	2-1 (1 min)	2-2 (1 min)	2-3 (1 min)	Replicate #3	3-1 (1 min)	3-2 (1 min)	3-3 (1 min)	
Nematoda	133.2	890.0	554.0	100.9	235.1	5436.7	4800.0	135.2	501.5	779.4	501.0	102.9	175.5	366.3
Tubificidae	33.3	4398.0	2386.0	741.6	1270.4	8897.8	5019.0	876.8	3002.0	11284.3	8519.0	911.1	1854.2	166.5
Naididae	3178.5	4262.3	1880.0	1543.8	838.5	10200.6	6446.0	1083.6	2671.0	7162.1	2511.0	2071.3	2579.8	15636.7
Enchytraeidae														
Aeolosoma	33.3									0.0				
Sididae						50.0	50.0							
Sida														1165.5
Diaphanosoma														66.6
Latona		2200.5	702.0	1298.7	199.8	1269.7	300.0	703.3	266.4	867.0	200.0	432.9	234.1	3396.6
Acroperus	600.4	383.0	50.0	166.5	166.5	932.4		599.4	333.0	766.1	200.0	399.6	166.5	33.3
Alona		66.6			66.6	67.6		1.0	66.6	266.6	200.0	66.6		834.5
Chydorus	33.3	33003.8	8152.0	12092.9	12758.9	56790.9	1400.0	20491.5	34899.4	52134.4	19202.0	22764.9	10167.5	16284.7
Eurycercus		2764.1	200.0	1831.5	732.6	4653.7	350.0	2339.0	1964.7	7908.5	2404.0	3232.1	2272.4	366.3
Graptoleberis		2270.3	901.0	33.3	1336.0	66.6		66.6		333.1	100.0	199.8	33.3	567.1
Ilyocryptus	33.3	134.3	101.0	33.3		2797.8	600.0	432.9	1764.9	3766.1	1200.0	1566.1	1000.0	2264.4
Leydigia		5554.7	2253.0	2533.8	767.9	8164.1	1600.0	3699.3	2864.8	7998.9	1901.0	4295.7	1802.2	1964.7
Macrothrix	266.4	2814.8	950.0	765.9	1098.9	1749.4	150.0	966.7	632.7	4097.7	1800.0	1098.9	1198.8	865.8
Pleuroxus	33.3	9431.8	1905.0	5761.9	1764.9	6029.7	400.0	2899.1	2730.6	14916.0	4901.0	4864.8	5150.2	6461.2
Daphnidae		51.0	51.0			116.6	50.0	66.6						
Daphnia						167.5		34.3	133.2	33.3			33.3	
Ceriodaphnia		816.0	150.0		666.0	3816.2	350.0	1367.3	2098.9	2065.6	1000.0	632.7	432.9	899.1
Simocephalus	66.6	7619.3	2255.0	3699.3	1665.0	11220.1	650.0	5573.1	4997.0	11899.2	3100.0	5699.3	3099.9	799.2
Cyclopoida	632.7	13434.6	3708.0	5361.3	4365.3	22150.7	1850.0	7138.2	13162.5	44758.6	13001.0	19043.3	12714.3	29771.2
Harpacticoida		0.0				50.0	50.0							
Ostracoda	666.0	15073.5	5905.0	7067.6	2100.9	23292.9	7200.0	6866.8	9226.1	26460.0	7100.0	8872.8	10487.2	22015.3
Ephemeroptera	200.8	50.0	50.0			66.6		33.3	33.3	233.1		99.9	133.2	432.9
Baetidae	1666.0	249.9	150.0	66.6	33.3	784.6	50.0	266.4	468.2	1771.3	400.0	804.2	567.1	33.3
Acerpenna	1911.1	33.3		33.3										
Baetis	36.3									107.0	106.0		1.0	
Callibaetis		173.5	4.0	136.2	33.3	444.1	200.0	204.8	39.3	528.6	117.0	204.8	206.8	34.3
Procloeon	306.7									0.0				33.3
Caenis	33.3	338.8	119.0	218.8	1.0	153.9	53.0	100.9		381.5	214.0	99.9	67.6	1969.7
Ephemerellidae	1266.4									0.0				
Ephemera	5.0	1.0		1.0										
Hexagenia		12.0	1.0	7.0	4.0					1.0	1.0			
Heptageniidae	202.8									1.0	1.0			
Heptagenia	40.3													
Maccaffertium	2.0													
Leptophlebiidae	599.4	186.3	152.0	1.0	33.3	33.3		33.3		342.2	208.0	99.9	34.3	33.3
Leptophlebia	34.3	3.0	2.0	1.0		1.0			1.0	38.3	4.0	34.3		

Appendix 2 Benthic invertebrate community composition recorded in three agricultural streams in 2006 (con't)

Taxa	210 µm Mesh Size														
	Rose Creek	Blindman River													Strawberry Creek
		Replicate #1	1-1 (1 min)	1-2 (1 min)	1-3 (1 min)	Replicate #2	2-1 (1 min)	2-2 (1 min)	2-3 (1 min)	Replicate #3	3-1 (1 min)	3-2 (1 min)	3-3 (1 min)	
Siphloplecton	43.3													
Tricorythodes	33.3													
Trichoptera														
Brachycentrus	9.0													
Helicopsyche	2.0													
Arctopsyche	1.0													
Cheumatopsyche	33.3													
Hydropsyche	36.3	1.0	1.0											
Hydroptilidae	1.0					33.3			33.3					
Hydroptilia	1098.9													
Lepidostoma	133.2													
Leptoceridae	66.6	99.9		99.9		33.3			33.3	434.1	201.0	66.6	166.5	166.5
Argraylea														
Ceraclea	33.3					1.0		1.0		67.6	1.0	33.3	33.3	
Mystacides						1.0		1.0		1.0	1.0			
Oecetis	73.6													
Amphicosmoecus														
Triaenodes										33.3		33.3		
Limnephilus/Philarctus										1.0	1.0			
Nemotaulius		2.0		1.0	1.0	1.0			1.0	45.3		39.3	6.0	
Phryganea		3.0		1.0	2.0	4.0	2.0	1.0	1.0					3.0
Ptilostomis		1.0			1.0	2.0		1.0	1.0					
Polycentropodidae	99.9	50.0	50.0											
Neureclipsis	1.0													
Polycentropus		51.0	51.0			8.0		3.0	5.0	1.0	1.0			
Psychomyia	33.3													
Plecoptera														
Pteronarcys														
Perlodidae														
Skwala	2.0													
Taeniopteryx	234.1													
Chironomidae	66.6	33.3			33.3	2.0		1.0	1.0	135.3	102.0	33.3		3398.6
Chironomini	2336.0	2862.8	981.0	1078.6	803.2	4083.5	2571.0	407.6	1104.9	3264.2	1727.0	737.3	799.9	3032.3
Tanytarsini	2299.7	2682.9	1243.0	701.3	738.6	1842.7	1209.0	166.5	467.2	1305.3	605.0	334.0	366.3	566.1
Orthocladiinae	1335.0	851.4	251.0	200.8	399.6	1470.3	51.0	730.3	689.0	5645.5	2466.0	1636.7	1542.8	2801.2
Tanypodinae	2336.0	3309.9	867.0	1273.4	1169.5	2920.0	1911.0	436.9	572.1	3834.7	1524.0	1037.3	1273.4	501.5
Ceratopogoninae	534.8	53.0	52.0	1.0		441.3	408.0		33.3	105.9	5.0	99.9	1.0	
Chaoborus		1.0	1.0											
Dicranota	33.3													
Hemerodromia	33.3													
Sisyra										1.0			1.0	
Tabanidae		3.0		3.0		2.0	1.0		1.0	1.0	1.0			
Gammarus lacustris		27.0	10.0	13.0	4.0	113.3	5.0	59.3	49.0	191.0	98.0	55.0	38.0	4.0
Hyalella azteca		1338.3	301.0	601.4	435.9	3213.3	501.0	1378.3	1334.0	7750.9	2974.0	2909.1	1867.8	134.2
Notonectidae						1.0		1.0		3.0	1.0		2.0	

Appendix 2 Benthic invertebrate community composition recorded in three agricultural streams in 2006 (con't)

Taxa	210 um Mesh Size													
	Rose Creek	Blindman River												Strawberry Creek
		Replicate #1	1-1 (1 min)	1-2 (1 min)	1-3 (1 min)	Replicate #2	2-1 (1 min)	2-2 (1 min)	2-3 (1 min)	Replicate #3	3-1 (1 min)	3-2 (1 min)	3-3 (1 min)	
Corixidae	35.3	15.0	3.0	12.0		109.6	1.0	104.6	4.0	26.0	8.0	8.0	10.0	69.6
Coleoptera										33.3			33.3	
Elmidae	99.9	11.0	11.0						33.3					
Dubiraphia	66.6	248.1	9.0	104.9	134.2	49.3	14.0	2.0	33.3	314.8	111.0	136.2	67.6	33.3
Optioservus	33.3									33.3		33.3		
Haliplidae														
Haliplus		44.3	8.0	2.0	34.3	1.0	1.0			35.3		2.0	33.3	33.3
Dytisicidae		2.0	1.0	1.0						5.0	1.0	4.0		66.6
Agabus/Ilybius						3.0	1.0		2.0	1.0		1.0		
Colymbetes										6.0		6.0		
Aeshna		2.0	1.0		1.0	1.0			1.0					
Gomphidae														
Ophiogomphus	89.6													
Epitheca														
Somatochlora	1.0													1.0
Libellula														1.0
Enallagma/Coenagrion		67.0	38.0	8.0	21.0	30.0		19.0	11.0	172.3	44.0	101.3	27.0	1.0
Gastropoda	99.9													
Ferrissia rivularis	36.3													
Lymnaea		118.6	51.0	67.6		69.6	1.0	35.3	33.3	257.2	104.0	107.9	45.3	
Physidae										133.3	100.0		33.3	
Physa	36.3	16.0	6.0	1.0	9.0	2.0	2.0			369.5	108.0	163.9	97.6	4.0
Planorbidae	33.3									99.9		99.9		
Helisoma						1.0			1.0					
Valvata		279.4	2.0	201.8	75.6	129.6	54.0	36.3	39.3	186.6	103.0	41.3	42.3	
Unionidae		1.0	1.0											
Sphaeriidae	99.9	506.7	202.0	134.2	170.5	261.8	50.0	33.3	178.5	767.6	700.0		67.6	
Pisidium	156.2	447.1	201.0	135.2	110.9	623.1	314.0	103.9	205.2	194.6	102.0	42.3	50.3	7.0
Sphaerium	9.0	16.0	7.0	3.0	6.0	1.0	1.0			2.0	2.0			2.0
Hirudinea														
Glossiphoniidae										2.0		2.0		
Glossiphomis complanata		2.0	1.0		1.0									
Hellobdela stagnalis										101.0	101.0			
Placobdella														
Erpobdellidae														
Nephelopsis obscura														
Acari	1302.7	268.5	101.0	100.9	66.6	852.5	350.0	302.7	199.8	135.2	1.0	34.3	99.9	1431.9
Hydra	33.3	167.6	100.0	1.0	66.6	99.9		66.6	33.3	66.6		66.6		299.7
Sialis		70.0	56.0	5.0	9.0	13.0	4.0	6.0	3.0	1.0	1.0			
Turbellaria	99.9	166.5		133.2	33.3	66.6		33.3	33.3	366.3		333.0	33.3	266.4
Hymenoptera		50.0	50.0											
Thysanoptera														
Spider										1.0	1.0			

Appendix 2 Benthic invertebrate community composition recorded in three agricultural streams in 2006 (con't)

	210 um Mesh Size														
Taxa	Rose Creek	Blindman River													Strawberry Creek
		Replicate #1	1-1 (1 min)	1-2 (1 min)	1-3 (1 min)	Replicate #2	2-1 (1 min)	2-2 (1 min)	2-3 (1 min)	Replicate #3	3-1 (1 min)	3-2 (1 min)	3-3 (1 min)	
Derived Variables or 'metrics'														
Total Numbers	**25157**	**120086**	**37238**	**48382**	**34465**	**185892**	**39020**	**59910**	**86995**	**227033**	**80086**	**85796**	**61151**	**119286**
Nematoda	133.2	890.0	554.0	100.9	235.1	5436.7	4800.0	135.2	501.5	779.4	501.0	102.9	175.5	366.3
Oligochaeta	3245.1	8660.3	4266.0	2285.4	2108.9	19098.4	11465.0	1960.4	5673.0	18446.4	11030.0	2982.4	4434.0	15803.2
Cladocera	1033.3	67110.2	17670.0	28217.1	21223.1	97892.3	5900.0	39240.1	52752.2	107052.5	36208.0	45253.4	25591.1	35969.0
Copepoda	632.7	13434.6	3708.0	5361.3	4365.3	22200.7	1900.0	7138.2	13162.5	44758.6	13001.0	19043.3	12714.3	29771.2
Ostracoda	666.0	15073.5	5905.0	7067.6	2100.9	23292.9	7200.0	6866.8	9226.1	26460.0	7100.0	8872.8	10487.2	22015.3
Ephemeroptera	6381.0	1047.8	478.0	464.9	104.9	1483.5	303.0	638.7	541.8	3404.0	1051.0	1343.0	1010.0	2536.8
Trichptera	1622.4	207.9	102.0	101.9	4.0	83.6	2.0	7.0	74.6	583.3	205.0	172.5	205.8	169.5
Plecoptera	236.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae	8373.3	9740.3	3342.0	3254.1	3144.2	10318.5	5742.0	1742.3	2834.2	14185.0	6424.0	3778.6	3982.4	10299.7
Diptera	601.4	57.0	53.0	4.0	0.0	443.3	409.0	0.0	34.3	107.9	6.0	99.9	2.0	0.0
Amphipoda	0.0	1365.3	311.0	614.4	439.9	3326.6	506.0	1437.6	1383.0	7941.9	3072.0	2964.1	1905.8	138.2
Hemiptera	35.3	15.0	3.0	12.0	0.0	110.6	1.0	105.6	4.0	29.0	9.0	8.0	12.0	69.6
Coleoptera	199.8	305.4	29.0	107.9	168.5	53.3	16.0	2.0	68.6	428.7	112.0	182.5	134.2	133.2
Odonata	90.6	69.0	39.0	8.0	22.0	31.0	0.0	19.0	12.0	172.3	44.0	101.3	27.0	3.0
Mollusca	470.9	1384.8	470.0	542.8	372.0	1088.1	422.0	208.8	457.3	2010.7	1219.0	455.3	336.4	13.0
Hirudinea	0.0	2.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	103.0	101.0	2.0	0.0	0.0
Acari	1302.7	268.5	101.0	100.9	66.6	852.5	350.0	302.7	199.8	135.2	1.0	34.3	99.9	1431.9
others	133.2	454.1	206.0	139.2	108.9	179.5	4.0	105.9	69.6	434.9	2.0	399.6	33.3	566.1
Number of Taxa	**67**	**65**	**54**	**49**	**45**	**62**	**41**	**48**	**51**	**72**	**55**	**52**	**48**	**47**
Nematoda	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Oligochaeta	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0	2.0	2.0	2.0	2.0
Cladocera	6.0	13.0	12.0	10.0	11.0	15.0	11.0	14.0	12.0	13.0	12.0	12.0	12.0	14.0
Copepoda	1.0	2.0	1.0	1.0	1.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Ostracoda	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Ephemeroptera	15.0	9.0	7.0	8.0	5.0	6.0	3.0	5.0	4.0	11.0	8.0	6.0	6.0	6.0
Trichptera	14.0	7.0	3.0	3.0	3.0	8.0	1.0	5.0	6.0	7.0	5.0	4.0	3.0	2.0
Plecoptera	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae	5.0	5.0	4.0	4.0	5.0	5.0	4.0	5.0	5.0	5.0	5.0	5.0	4.0	5.0
Diptera	3.0	3.0	2.0	2.0	0.0	2.0	2.0	0.0	2.0	3.0	2.0	1.0	2.0	0.0
Amphipoda	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Hemiptera	1.0	1.0	1.0	1.0	0.0	2.0	1.0	2.0	1.0	2.0	2.0	1.0	2.0	1.0
Coleoptera	3.0	4.0	4.0	3.0	2.0	3.0	3.0	1.0	3.0	7.0	2.0	6.0	3.0	3.0
Odonata	2.0	2.0	2.0	1.0	2.0	2.0	0.0	1.0	2.0	1.0	1.0	1.0	1.0	3.0
Mollusca	7.0	7.0	7.0	6.0	5.0	7.0	6.0	4.0	5.0	8.0	7.0	5.0	6.0	3.0
Hirudinea	0.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	2.0	1.0	1.0	0.0	0.0
Acari	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
others	2.0	4.0	3.0	3.0	3.0	3.0	1.0	3.0	3.0	4.0	2.0	2.0	1.0	2.0

Appendix 2 Benthic invertebrate community composition recorded in three agricultural streams in 2006 (con't)

Taxa	Rose Creek	Replicate #1	1-1 (1 min)	1-2 (1 min)	1-3 (1 min)	Replicate #2	2-1 (1 min)	2-2 (1 min)	2-3 (1 min)	Replicate #3	3-1 (1 min)	3-2 (1 min)	3-3 (1 min)	Strawberry Creek
	210 um Mesh Size													
		Blindman River												
Percentages														
Nematoda	0.5	0.7	1.5	0.2	0.7	2.9	12.3	0.2	0.6	0.3	0.6	0.1	0.3	0.3
Oligochaeta	12.9	7.2	11.5	4.7	6.1	10.3	29.4	3.3	6.5	8.1	13.8	3.5	7.3	13.2
Cladocera	4.1	55.9	47.5	58.3	61.6	52.7	15.1	65.5	60.6	47.2	45.2	52.7	41.8	30.2
Copepoda	2.5	11.2	10.0	11.1	12.7	11.9	4.9	11.9	15.1	19.7	16.2	22.2	20.8	25.0
Ostracoda	2.6	12.6	15.9	14.6	6.1	12.5	18.5	11.5	10.6	11.7	8.9	10.3	17.1	18.5
Ephemeroptera	25.4	0.9	1.3	1.0	0.3	0.8	0.8	1.1	0.6	1.5	1.3	1.6	1.7	2.1
Trichptera	6.4	0.2	0.3	0.2	0.0	0.0	0.0	0.0	0.1	0.3	0.3	0.2	0.3	0.1
Plecoptera	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae	33.3	8.1	9.0	6.7	9.1	5.6	14.7	2.9	3.3	6.2	8.0	4.4	6.5	8.6
Diptera	2.4	0.0	0.1	0.0	0.0	0.2	1.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Amphipoda	0.0	1.1	0.8	1.3	1.3	1.8	1.3	2.4	1.6	3.5	3.8	3.5	3.1	0.1
Hemiptera	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1
Coleoptera	0.8	0.3	0.1	0.2	0.5	0.0	0.0	0.0	0.1	0.2	0.1	0.2	0.2	0.1
Odonata	0.4	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0
Mollusca	1.9	1.2	1.3	1.1	1.1	0.6	1.1	0.3	0.5	0.9	1.5	0.5	0.6	0.0
Hirudinea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Acari	5.2	0.2	0.3	0.2	0.2	0.5	0.9	0.5	0.2	0.1	0.0	0.0	0.2	1.2
others	0.5	0.4	0.6	0.3	0.3	0.1	0.0	0.2	0.1	0.2	0.0	0.5	0.1	0.5
% Hydropsychidae/ Trichoptera	4.35	0.48	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% EPT	32.75	1.05	1.56	1.17	0.32	0.84	0.78	1.08	0.71	1.76	1.57	1.77	1.99	2.27

Appendix 2 Benthic invertebrate community composition recorded in three agricultural streams in 2006 (con't)

Taxa	400 µm Mesh Size													
	Rose Creek	Blindman River												Strawberry Creek
		Replicate #1	1-1 (1 min)	1-2 (1 min)	1-3 (1 min)	Replicate #2	2-1 (1 min)	2-2 (1 min)	2-3 (1 min)	Replicate #3	3-1 (1 min)	3-2 (1 min)	3-3 (1 min)	
Nematoda	25.0	17.3	16.3		1.0	647.5	475.0	2.0	170.5	33.3		33.3		66.6
Tubificidae	12.5	2497.0	822.8	602.4	1071.8	7838.6	2727.0	3272.1	1839.5	9955.2	7813.0	1806.2	336.0	33.3
Naididae	1470.5	4931.7	928.9	1612.4	2390.4	9095.0	3740.0	2119.9	3235.1	7584.3	3204.0	2705.3	1675.0	8691.7
Enchytraeidae	12.5													
Aeolosoma														532.8
Sididae														
Sida														
Diaphanosoma														33.3
Latona		1633.4	516.8	765.9	350.7	1423.8	225.0	466.2	732.6	433.0	100.0	166.5	166.5	1831.5
Acroperus										33.3			33.3	
Alona														
Chydorus						1.0		1.0		2.0		1.0	1.0	2.0
Eurycercus		1390.7	271.7	968.7	150.3	3973.6	575.0	1333.0	2065.6	6432.7	1800.0	1466.2	3166.5	
Graptoleberis														
Ilyocryptus						1026.1	125.0	267.4	633.7	1216.3	850.0	233.1	133.2	568.1
Leydigia		645.5	128.7	299.7	217.1	1760.8	226.0	700.3	834.5	1466.9	701.0	566.1	199.8	233.1
Macrothrix														
Pleuroxus		34.3		34.3		124.9	25.0	33.3	66.6	51.0	50.0		1.0	
Daphnidae		14.3	14.3			33.3			33.3					
Daphnia						33.3		33.3						
Ceriodaphnia		147.7	114.4	33.3		1416.5	250.0	699.3	467.2	899.3	200.0	299.7	399.6	
Simocephalus	37.5	8654.8	471.9	7931.4	251.5	15972.3	950.0	5527.8	9494.5	6226.4	1956.0	2067.6	2202.8	333.0
Cyclopoida		3037.8	688.4	1764.9	584.5	11942.4	2350.0	3663.0	5929.4	8189.4	3253.0	2601.4	2335.0	3531.8
Harpacticoida														
Ostracoda	100.0	4453.0	1102.1	2597.4	753.5	8846.6	1775.0	2235.1	4836.5	11934.1	3701.0	3066.6	5166.5	3999.0
Ephemeroptera	38.5	1.0	1.0			25.0	25.0			250.0	250.0			33.3
Baetidae	75.0	65.3	15.3	33.3	16.7	492.2	25.0	233.1	234.1	1218.6	150.0	568.1	500.5	
Acerpenna	1330.0													
Baetis	52.0													
Callibaetis		214.4	60.2	153.2	1.0	553.4	280.0	37.3	236.1	693.0	354.0	138.2	200.8	66.6
Procloeon	168.5	16.3	14.3	2.0						1.0		1.0		33.3
Caenis	37.5	189.2	36.6	131.9	20.7	203.8	2.0	68.6	133.2	488.9	51.0	235.1	202.8	2077.6
Ephemerellidae	350.0													
Ephemera	17.5													
Hexagenia		21.0	8.0	8.0	5.0					1.0		1.0		
Heptageniidae	38.5													
Heptagenia	14.5													
Maccaffertium														
Leptophlebiidae	264.5	129.7	2.0	76.6	51.1	66.6			66.6	135.3	100.0	35.3		
Leptophlebia	25.0	151.2	30.6	102.9	17.7					100.9		34.3	66.6	

Appendix 2 Benthic invertebrate community composition recorded in three agricultural streams in 2006 (con't)

Taxa	400 um Mesh Size													
	Rose Creek	Blindman River												Strawberry Creek
		Replicate #1	1-1 (1 min)	1-2 (1 min)	1-3 (1 min)	Replicate #2	2-1 (1 min)	2-2 (1 min)	2-3 (1 min)	Replicate #3	3-1 (1 min)	3-2 (1 min)	3-3 (1 min)	
Siphloplecton	45.5													
Tricorythodes		33.3		33.3										
Trichoptera	15.5													33.3
Brachycentrus	2.0													
Helicopsyche	25.0													
Arctopsyche														
Cheumatopsyche														
Hydropsyche														
Hydroptilidae														
Hydroptilia	37.5													
Lepidostoma	178.0	1.0		1.0										
Leptoceridae	1.0	61.9	28.6	33.3		99.9		33.3	66.6	116.6	50.0	33.3	33.3	
Argraylea						58.3	25.0		33.3	1.0			1.0	
Ceraclea	37.5									66.6		33.3	33.3	
Mystacides	12.5									50.0	50.0			34.3
Oecetis	77.0	1.0	1.0							33.3		33.3		101.9
Amphicosmoecus	1.0													
Triaenodes														
Limnephilus/Philarctus														
Nemotaulius		7.0	1.0	6.0		2.0		1.0	1.0	5.0	1.0	1.0	3.0	
Phryganea						4.0	1.0		3.0	1.0	1.0			3.0
Ptilostomis	1.0	1.0	1.0			2.0		2.0		3.0	2.0		1.0	
Polycentropodidae		33.3		33.3										
Neureclipsis	88.5													
Polycentropus		36.4	1.0		35.4	45.3	1.0	6.0	38.3	3.0	1.0	1.0	1.0	
Psychomyia														
Plecoptera	37.5													
Pteronarcys	1.0													
Perlodidae	25.0													
Skwala	3.0													
Taeniopteryx	254.0													
Chironomidae	37.5	64.3	14.3	33.3	16.7					218.5	50.0	133.2	35.3	2.0
Chironomini	229.0	1357.7	375.5	368.0	614.2	2660.4	1042.0	605.4	1013.0	1357.8	459.0	553.8	345.0	1602.4
Tanytarsini	125.0	2782.7	450.3	1076.6	1255.8	575.7	275.0	67.6	233.1	500.7	200.0	200.8	99.9	269.4
Orthocladiinae	162.5	147.5	60.2	69.6	17.7	1618.2	79.0	403.3	1135.9	2133.9	676.0	671.0	786.9	133.2
Tanypodinae	212.5	2117.5	462.3	922.8	732.4	1218.2	402.0	242.1	574.1	1568.1	655.0	476.2	436.9	568.1
Ceratopogoninae	150.0	82.7	28.6	3.0	51.1	324.8	125.0	133.2	66.6	266.5	100.0	66.6	99.9	566.1
Chaoborus														
Dicranota														
Hemerodromia	25.0													
Sisyria										1.0	1.0			
Tabanidae	1.0	1.0			1.0	6.0	3.0	1.0	2.0	1.0	1.0			1.0
Gammarus lacustris		44.0	12.0	24.0	8.0	308.6	80.0	143.6	85.0	269.6	65.0	110.3	94.3	1.0
Hyallella azteca	37.5	1490.5	403.4	916.1	171.0	4548.8	326.0	1855.5	2367.3	7955.3	2913.0	2470.2	2572.1	66.6
Notonectidae		7.0		7.0		2.0		1.0	1.0	3.0		3.0		

Appendix 2 Benthic invertebrate community composition recorded in three agricultural streams in 2006 (con't)

Taxa	400 um Mesh Size													
	Rose Creek	Blindman River												Strawberry Creek
		Replicate #1	1-1 (1 min)	1-2 (1 min)	1-3 (1 min)	Replicate #2	2-1 (1 min)	2-2 (1 min)	2-3 (1 min)	Replicate #3	3-1 (1 min)	3-2 (1 min)	3-3 (1 min)	
Corixidae	15.5	65.6	16.3	48.3	1.0	88.3	28.0	18.0	42.3	44.0	16.0	9.0	19.0	103.9
Coleoptera		33.3		33.3						50.0	50.0			
Elmidae	25.0	5.0	1.0	4.0						1.0	1.0			
Dubiraphia	37.5	559.7	216.2	172.5	171.0	338.0	1.0	136.2	200.8	205.8	3.0	101.9	100.9	33.3
Optioservus	101.0	1.0		1.0						1.0		1.0		
Haliplidae		28.6	28.6											
Haliplus		18.7		2.0	16.7	33.3			33.3	33.3			33.3	
Dytisicidae	12.5					3.0		1.0	2.0	5.0	3.0		2.0	1.0
Agabus/Ilybius										11.0	4.0	5.0	2.0	
Colymbetes										7.0	1.0		6.0	
Aeshna		5.0	2.0	1.0	2.0	1.0			1.0	2.0	1.0		1.0	5.0
Gomphidae	51.0									0.0				
Ophiogomphus	29.5									0.0				
Epitheca						1.0		1.0						
Somatochlora														1.0
Libellula														4.0
Enallagma/Coenagrion		83.0	33.3	26.0	23.7	40.0	2.0	26.0	12.0	261.6	97.0	94.3	70.3	5.0
Gastropoda	114.5	66.7		33.3	33.4	100.9		33.3	67.6	33.3			33.3	
Ferrissia rivularis	12.5													
Lymnaea		39.0	17.3	3.0	18.7	102.9		69.6	33.3	133.6	55.0	5.0	73.6	
Physidae	12.5									33.3		33.3		33.3
Physa	25.0	134.9	54.9	56.3	23.7	72.6	1.0	67.6	4.0	301.5	123.0	73.6	104.9	6.0
Planorbidae	26.0	260.4	42.9	200.8	16.7	66.6		66.6		152.0	150.0		2.0	
Helisoma														
Valvata		968.1	173.6	569.1	205.4	578.0	231.0	247.1	99.9	648.5	482.0	166.5		1.0
Unionidae														
Sphaeriidae	63.5	529.8	128.7	233.1	168.0	583.9	151.0	133.2	299.7	233.3	200.0	33.3		66.6
Pisidium	143.5	995.6	101.1	541.8	352.7	1826.5	625.0	631.4	570.1	1267.8	1068.0	199.8		99.9
Sphaerium	27.0	5.0		2.0	3.0	2.0	2.0							
Hirudinea						1.0			1.0					
Glossiphoniidae										1.0	1.0			
Glossiphonis complanata		3.0			3.0					2.0			2.0	
Helobdela stagnalis		17.7		1.0	16.7	51.0	51.0			33.3		33.3		
Placobdella														1.0
Erpobdellidae						2.0	1.0	1.0						
Nephelopsis obscura					2.0									
Acari	262.5	293.6	59.2	134.2	100.2	1270.0	600.0	468.2	201.8	201.8	2.0	133.2	66.6	832.5
Hydra	25.0	169.1	85.8	66.6	16.7	66.6		66.6		50.0	50.0			266.4
Sialis		15.0	2.0	7.0	6.0	19.0	4.0	3.0	12.0					
Turbellaria														
Hymenoptera														
Thysanoptera														33.3
Spider	12.5									1.0	1.0			

Appendix 2 Benthic invertebrate community composition recorded in three agricultural streams in 2006 (con't)

Taxa	400 um Mesh Size													
	Rose Creek	Blindman River												Strawberry Creek
		Replicate #1	1-1 (1 min)	1-2 (1 min)	1-3 (1 min)	Replicate #2	2-1 (1 min)	2-2 (1 min)	2-3 (1 min)	Replicate #3	3-1 (1 min)	3-2 (1 min)	3-3 (1 min)	
Derived Variables or 'metrics'														
Total Numbers	**6889**	**40813**	**8046**	**22802**	**9967**	**82199**	**17831**	**26158**	**38210**	**75615**	**32066**	**21702**	**21847**	**26943**
Nematoda	25.0	17.3	16.3	0.0	1.0	647.5	475.0	2.0	170.5	33.3	0.0	33.3	0.0	66.6
Oligochaeta	1495.5	7428.7	1751.7	2214.8	3462.2	16933.6	6467.0	5392.0	5074.6	17539.5	11017.0	4511.5	2011.0	9257.8
Cladocera	37.5	12520.7	1517.8	10033.3	969.6	25765.6	2376.0	9061.6	14328.0	16760.9	5657.0	4800.2	6303.7	3001.0
Copepoda	0.0	3037.8	688.4	1764.9	584.5	11942.4	2350.0	3663.0	5929.4	8189.4	3253.0	2601.4	2335.0	3531.8
Ostracoda	100.0	4453.0	1102.1	2597.4	753.5	8846.6	1775.0	2235.1	4836.5	11934.1	3701.0	3066.6	5166.5	3999.0
Ephemeroptera	2457.0	821.4	168.0	541.2	112.2	1341.0	332.0	339.0	670.0	2888.7	905.0	1013.0	970.7	2210.8
Trichptera	476.5	141.6	32.6	73.6	35.4	211.5	27.0	42.3	142.2	279.5	105.0	101.9	72.6	172.5
Plecoptera	320.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae	766.5	6469.7	1362.6	2470.3	2636.8	6072.5	1798.0	1318.4	2956.1	5779.0	2040.0	2035.0	1704.0	2575.1
Diptera	176.0	83.7	28.6	3.0	52.1	330.8	128.0	134.2	68.6	268.5	102.0	66.6	99.9	567.1
Amphipoda	37.5	1534.5	415.4	940.1	179.0	4857.4	406.0	1999.1	2452.3	8224.9	2978.0	2580.5	2666.4	67.6
Hemiptera	15.5	72.6	16.3	55.3	1.0	90.3	28.0	19.0	43.3	47.0	16.0	12.0	19.0	103.9
Coleoptera	176.0	646.3	245.8	212.8	187.7	374.3	1.0	137.2	236.1	314.1	62.0	107.9	144.2	34.3
Odonata	80.5	88.0	35.3	27.0	25.7	42.0	2.0	27.0	13.0	263.6	98.0	94.3	71.3	15.0
Mollusca	424.5	2999.5	518.5	1659.4	821.6	3333.4	1010.0	1248.8	1074.6	2803.3	2078.0	511.5	213.8	206.8
Hirudinea	0.0	20.7	0.0	1.0	21.7	54.0	52.0	1.0	1.0	36.3	1.0	33.3	2.0	1.0
Acari	262.5	293.6	59.2	134.2	100.2	1270.0	600.0	468.2	201.8	201.8	2.0	133.2	66.6	832.5
others	37.5	184.1	87.8	73.6	22.7	85.6	4.0	69.6	12.0	51.0	51.0	0.0	0.0	299.7
Number of Taxa	**63**	**60**	**47**	**51**	**44**	**56**	**39**	**46**	**46**	**69**	**51**	**46**	**45**	**45**
Nematoda	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	0.0	1.0
Oligochaeta	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0
Cladocera	1.0	7.0	6.0	6.0	4.0	10.0	7.0	9.0	8.0	9.0	7.0	7.0	9.0	6.0
Copepoda	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Ostracoda	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Ephemeroptera	13.0	9.0	8.0	8.0	6.0	5.0	4.0	3.0	4.0	8.0	5.0	7.0	4.0	4.0
Trichptera	12.0	7.0	5.0	4.0	1.0	6.0	3.0	4.0	5.0	9.0	6.0	5.0	6.0	4.0
Plecoptera	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae	5.0	5.0	5.0	5.0	5.0	4.0	4.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0
Diptera	3.0	2.0	1.0	1.0	2.0	2.0	2.0	2.0	2.0	3.0	3.0	1.0	1.0	2.0
Amphipoda	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Hemiptera	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.0	2.0	2.0	1.0	2.0	1.0	1.0
Coleoptera	4.0	6.0	3.0	5.0	2.0	3.0	1.0	2.0	3.0	8.0	6.0	3.0	5.0	2.0
Odonata	2.0	2.0	2.0	2.0	2.0	3.0	1.0	2.0	2.0	4.0	2.0	1.0	2.0	4.0
Mollusca	8.0	8.0	6.0	8.0	8.0	8.0	5.0	7.0	6.0	8.0	6.0	6.0	4.0	5.0
Hirudinea	0.0	2.0	0.0	1.0	3.0	3.0	2.0	1.0	1.0	3.0	1.0	1.0	1.0	1.0
Acari	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
others	2.0	2.0	2.0	2.0	2.0	2.0	1.0	2.0	1.0	2.0	2.0	0.0	0.0	2.0

Appendix 2 Benthic invertebrate community composition recorded in three agricultural streams in 2006 (con't)

Taxa	400 um Mesh Size													
	Rose Creek	Blindman River												Strawberry Creek
		Replicate #1	1-1 (1 min)	1-2 (1 min)	1-3 (1 min)	Replicate #2	2-1 (1 min)	2-2 (1 min)	2-3 (1 min)	Replicate #3	3-1 (1 min)	3-2 (1 min)	3-3 (1 min)	
Percentages														
Nematoda	0.4	0.0	0.2	0.0	0.0	0.8	2.7	0.0	0.4	0.0	0.0	0.2	0.0	0.2
Oligochaeta	21.7	18.2	21.8	9.7	34.7	20.6	36.3	20.6	13.3	23.2	34.4	20.8	9.2	34.4
Cladocera	0.5	30.7	18.9	44.0	9.7	31.3	13.3	34.6	37.5	22.2	17.6	22.1	28.9	11.1
Copepoda	0.0	7.4	8.6	7.7	5.9	14.5	13.2	14.0	15.5	10.8	10.1	12.0	10.7	13.1
Ostracoda	1.5	10.9	13.7	11.4	7.6	10.8	10.0	8.5	12.7	15.8	11.5	14.1	23.6	14.8
Ephemeroptera	35.7	2.0	2.1	2.4	1.1	1.6	1.9	1.3	1.8	3.8	2.8	4.7	4.4	8.2
Trichptera	6.9	0.3	0.4	0.3	0.4	0.3	0.2	0.2	0.4	0.4	0.3	0.5	0.3	0.6
Plecoptera	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae	11.1	15.9	16.9	10.8	26.5	7.4	10.1	5.0	7.7	7.6	6.4	9.4	7.8	9.6
Diptera	2.6	0.2	0.4	0.0	0.5	0.4	0.7	0.5	0.2	0.4	0.3	0.3	0.5	2.1
Amphipoda	0.5	3.8	5.2	4.1	1.8	5.9	2.3	7.6	6.4	10.9	9.3	11.9	12.2	0.3
Hemiptera	0.2	0.2	0.2	0.2	0.0	0.1	0.2	0.1	0.1	0.1	0.0	0.1	0.1	0.4
Coleoptera	2.6	1.6	3.1	0.9	1.9	0.5	0.0	0.5	0.6	0.4	0.2	0.5	0.7	0.1
Odonata	1.2	0.2	0.4	0.1	0.3	0.1	0.0	0.1	0.0	0.3	0.3	0.4	0.3	0.1
Mollusca	6.2	7.3	6.4	7.3	8.2	4.1	5.7	4.8	2.8	3.7	6.5	2.4	1.0	0.8
Hirudinea	0.0	0.1	0.0	0.0	0.2	0.1	0.3	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Acari	3.8	0.7	0.7	0.6	1.0	1.5	3.4	1.8	0.5	0.3	0.0	0.6	0.3	3.1
others	0.5	0.5	1.1	0.3	0.2	0.1	0.0	0.3	0.0	0.1	0.2	0.0	0.0	1.1
% Hydropsychidae/ Trichoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% EPT	47.24	2.36	2.49	2.70	1.48	1.89	2.01	1.46	2.13	4.19	3.15	5.14	4.78	8.85

Appendix 3 Epilithic algal community composition recorded in three agricultural streams in 2006

Stream Name:	Rose Creek		Blindman R. #1		Blindman R. #2		Blindman R. #3		Strawberry Creek	
Date Sampled:	30-Aug-06		5-Sep-06		5-Sep-06		5-Sep-06		31-Aug-06	
	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass
Bacilariophyceae (Diatoms)										
Achananthes delicatula (Kuetzing) Grunow	0	0	9884	3.203	3503	0.694	4170	1.52	1786	0.394
Achnanthes lanceolata (Brebisson) Grunow	5530	0.553	34596	3.243	17517	1.752	20854	2.085	7147	0.715
Achnanthes minutissima Kuetzing	29496	0.995	98848	5.931	36202	1.14	46921	2.628	477070	16.101
Amphora lybica Ehrenberg	0	0	0	0	2335	0.2	3128	0.205	0	0
Amphora pediculus (Kuetzing) Grunow	11061	0.18	29654	0.483	2335	0.041	8341	0.116	0	0
Amphipleura pellucida Kuetzing	1843	2.301	9884	8.224	2335	2.616	0	0	17867	18.861
Caloneis bacillum (Grunow) Cleve	7374	0.83	9884	0.68	0	0	0	0	21441	2.144
Caloneis sp	0	0	0	0	0	0	0	0	1786	0.335
Cocconeis pediculus Ehrenberg	36870	117.883	9884	58.123	9342	54.935	5213	30.656	0	0
Cocconeis placentula var lineata (Ehrenberg) Van Heurck	134575	130.774	242178	102.926	162328	73.048	120953	51.405	0	0
Craticula halophila (Grunow et Van Heurck) D. G. Mann	0	0	0	0	0	0	3128	3.363	0	0
Cyclotella meneghiniana Kuetzing	0	0	9884	15.9	2335	0.917	8341	5.661	0	0
Cyclotella ocellata Pantocsek	0	0	2471	0.97	0	0	0	0	0	0
Cymbella microcephala Grunow	0	0	0	0	1167	0.032	0	0	121501	3.313
Cymbella minuta Hilse	5530	0.394	0	0	0	0	0	0	8933	0.468
Cymbella perpusilla Cleve Euler	0	0	0	0	0	0	0	0	0	0
Cymbella silesiaca Bleisch ex. Rabenhorst	1843	0.293	0	0	0	0	0	0	1786	0.299
Cymbella sinuata Gregory	0	0	0	0	5839	0.214	1042	0.03	0	0
Denticula kuetzingii Grunow	0	0	0	0	0	0	0	0	35735	8.041
Denticula subtilis Grunow	0	0	0	0	0	0	0	0	0	0
Diatoma moniliformis Kuetzing	129045	15.324	0	0	0	0	0	0	0	0
Diatoma tenuis Agardh	0	0	0	0	0	0	0	0	0	0
Diatoma vulgaris Bory	0	0	0	0	0	0	0	0	7147	12.865
Didymosphaenia geminata (Lyngyb.) M. Schmidt	0	0	0	0	0	0	0	0	0	0
Diploneis puella (Schumann) Cleve	0	0	0	0	3503	0.175	2085	0.13	7147	1.487
Epithemia adnata (Kuetzing) Brebisson	97705	62.532	7413	7.414	26860	29.546	6256	6.256	0	0
Epithemia sorex Kuetzing	141949	84.034	39539	31.632	29195	23.357	18768	15.015	8933	5.289
Fragilaria vaucheriae (Kuetzing) Petersen	14748	1.062	0	0	0	0	0	0	0	0
Gomphonema acuminatum Ehrenberg	0	0	0	0	3503	5.132	0	0	1786	4.544
Gomphonema augur var sphaeophorum (Ehrenberg) Lange-Bertalot	0	0	0	0	1167	1.737	0	0	0	0
Gomphonema olivaceum (Hornemann) Brebisson	14748	6.4	32125	29.046	15181	10.295	9384	5.154	0	0
Gomphonema parvulum Kuetzing	0	0	7413	1.207	4671	0.95	5213	1.508	0	0
Gomphonema pumilum (Grunow) Reichardt & Lange-Bertalot	5530	0.625	0	0	2335	0.264	0	0	0	0
Gomphonema sp	0	0	4942	0.559	0	0	0	0	0	0
Hantzschia amphioxys (Ehrenberg) Grunow	0	0	0	0	0	0	0	0	1786	0.858
Mastogloia smithii Thwaites ex. W. Smith	0	0	0	0	2335	0.934	0	0	112567	92.868
Melosira varians (Agardh)	3687	7.819	0	0	0	0	0	0	0	0
Navicula lanceolata (Agardh) Ehrenberg	0	0	0	0	1167	1.46	0	0	0	0
Navicula agrestis Hustedt	0	0	27183	1.305	1167	0.065	0	0	0	0
Navicula bryophila Petersen	0	0	7413	0.741	0	0	0	0	0	0
Naviucula capitatoradiata Germain	14748	8.967	2471	1.463	12846	8.222	3128	2.407	7147	4.345
Navicula cincta (Ehrenberg) Ralfs	0	0	0	0	0	0	0	0	0	0
Navicula cryptocephala Kuetzing	3687	2.124	22240	11.743	29195	10.729	11469	5.873	1786	0.7

Appendix 3 Epilithic algal community composition recorded in three agricultural streams in 2006 (con't)

Stream Name:	Rose Creek		Blindman R. #1		Blindman R. #2		Blindman R. #3		Strawberry Ck	
Date Sampled:	30-Aug-06		5-Sep-06		5-Sep-06		5-Sep-06		31-Aug-06	
	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass
Navicula cryptotenella (Lange-Bertalot)	11061	3.794	24712	3.089	4671	0.584	12512	2.477	144729	18.091
Navicula capitata Ehrenberg	0	0	4942	0.89	0	0	0	0	0	0
Navicula decussis Oestrup	5530	2.212	0	0	0	0	0	0	0	0
Navicula gregaria Donkin	1843	0.431	7413	1.668	7006	2.232	3128	0.958	0	0
Navicula margalithii Lange-Bertalot	14748	18.435	0	0	3503	4.379	0	0	0	0
Navicula menisculus Schumann	1843	0.361	2471	0.712	0	0	1042	0.255	3573	0.447
Navicula miniscula Grunow	1843	0.115	0	0	0	0	0	0	0	0
Navicula notha Wallace	0	0	0	0	2335	0.462	0	0	0	0
Navicula pseudanglica Lange-Bertalot	0	0	7413	1.816	3503	1.277	0	0	0	0
Navicula pupula Kuetzing	0	0	2471	0.909	2335	0.747	1042	0.367	3573	1.144
Navicula radiosa Kuetzing	1843	3.595	2471	1.977	0	0	1042	1.825	0	0
Navicula schroeterii *Meister*	0	0	0	0	0	0	0	0	0	0
Navicula sp	0	0	4942	0.712	1167	0.841	0	0	3573	2.001
Navicula subminiscula Mangiun	0	0	0	0	0	0	0	0	0	0
Navicula subhamulata Grunow	0	0	4942	0.463	0	0	0	0	0	0
Navicula veneta Kuetzing	3687	0.461	22240	2.78	7006	0.963	15640	1.955	8933	1.117
Navicula viridula (Kuetzing) Ehrenberg	0	0	4942	19.928	0	0	0	0	0	0
Nitzschia acicularis (Kuetzing) W. Smith	0	0	0	0	2335	0.654	0	0	0	0
Nitzschia calida Grunow	0	0	0	0	2335	1.202	0	0	0	0
Nitzschia constricta (Kuetzing) Ralfs	0	0	7413	3.136	14013	5.928	2085	1.602	0	0
Nitzschia dissipata (Hantzsch) Grunow	68209	14.068	29654	7.414	14013	4.379	9384	2.346	0	0
Nitzschia fonticola Grunow	0	0	0	0	0	0	0	0	0	0
Nitzschia frustulum (Kuetzing) Grunow	3687	0.461	27183	3.398	12846	1.445	6256	0.782	58963	7.37
Nitzschia gracilis Hantzsch	0	0	0	0	0	0	0	0	14294	2.173
Nitzschia heufleriana Grunow	0	0	0	0	0	0	1042	1.126	0	0
Nitzschia inconspicua Grunow	0	0	2471	0.044	0	0	0	0	0	0
Nitzschia intermedia Hantzsch	0	0	4942	8.896	0	0	0	0	0	0
Navicula levidensis (W. Smith) Grunow	0	0	7413	15.43	10510	17.736	2085	0.547	0	0
Nitzschia linearis (Agardh) W. Smith	3687	2.65	0	0	0	0	2085	5.339	0	0
Nitzschia palea (Kuetzing) W. Smith	0	0	44481	9.452	7006	1.401	4170	0.667	7147	1.787
Nitzschia perminuta Lange-Bertalot	0	0	0	0	0	0	0	0	0	0
Nitzschia paleacae Grunow	5530	0.299	69193	6.366	8174	0.441	17725	1.702	0	0
Nitzschia recta Hantzsch	0	0	17298	33.732	5839	3.285	1042	2.369	0	0
Nitzschia sinuata var tabellaria (Grunow) Grunow	0	0	0	0	0	0	0	0	3573	1.144
Rhoicosphenia abbreviata (Agardh) Lange-Bertalot	0	0	17298	2.815	14013	2.737	10427	1.867	0	0
Rhopalodia gibba (Ehrenberg) O. Muller	7374	11.061	0	0	3503	6.131	0	0	35735	57.892
Rhopalodia musculus (Ketzing) O. Muller	0	0	0	0	0	0	0	0	3573	0.643
Stephanodiscus minutulus (Kuetzing) Cleve & Mueller	0	0	12356	2.484	0	0	1042	0.088	0	0
Surirella angusta Kuetzing	0	0	2471	1.421	3503	4.557	1042	0.86	0	0
Surirella brebisonii Krammer & Lange-Bertalot	0	0	0	0	1167	1.604	0	0	0	0
Surirella minuta Brebisson	0	0	0	0	1167	0.338	0	0	0	0
Synedra ulna (Nitzsch) Ehr.	1843	3.54	14827	16.681	3503	3.09	7298	16.35	1786	3.431
CYANOBACTERIA										
Anabaena sp	0	0	32125	0.454	61895	2.074	46921	5.307	0	0
Anabaenopsis cunningtonii R. Taylor	0	0	0	0	0	0	0	0	162597	5.449
Aphanocapsa elachista W. & G.S. West	0	0	0	0	0	0	0	0	142942	2.021
Chroococcus limneticus Lemmermann	0	0	0	0	0	0	0	0	7147	0.808
Gloeotrichia sp	175132	46.216	0	0	46713	10.566	62562	14.151	2287079	517.325
Leibleinia sp	0	0	284189	3.571	0	0	0	0	0	0
Merismopedia elegans A. Braun	0	0	0	0	0	0	0	0	50029	1.677
Merismopedia glauca (Ehrenberg) Naegeli	0	0	158157	28.404	0	0	22939	2.594	0	0
Merismopedia tenusissima Lemmermann	0	0	0	0	0	0	0	0	25014	0.105
Oscillatona limnetica Lemmerman	9217	0.116	69193	0.87	0	0	0	0	35735	0.449

Appendix 3 Epilithic algal community composition recorded in three agricultural streams in 2006

Stream Name:	Rose Creek		Blindman R. #1		Blindman R. #2		Blindman R. #3		Strawberry Ck	
Date Sampled:	30-Aug-06		5-Sep-06		5-Sep-06		5-Sep-06		31-Aug-06	
	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass
Phormidium sp1	110610	8.34	331142	24.968	159992	16.084	132423	13.313	62537	6.287
Phormidium sp2	18435	1.853	405278	63.661	64230	14.529	0	0	0	0
Planktolyngya limnetica Lemmermann	0	0	0	0	0	0	0	0	1786	0.022
Pseudanabaena limnetica Komarek	0	0	0	0	0	0	0	0	0	0
Tolypothrix sp	36870	14.826	197697	105.998	23356	7.191	93843	28.892	955927	216.226
CHLOROPHYCEAE										
Ankistrodesmus fasciculatus (Lundb.) Kom.-Legn.	3687	0.261	0	0	0	0	0	0	0	0
Ankistrodesmus gracilis (Reinsch) Kors.	0	0	0	0	0	0	1042	0.049	0	0
Ankistrodesmus spiralis (Turner) Lemmermann	0	0	0	0	0	0	0	0	3573	50.52
Cladophora sp	0	0	0	0	4671	15.849	0	0	76831	486.609
Cosmarium granatum Brebisson	0	0	0	0	0	0	0	0	3573	28.98
Cosmarium meneghinii Brebisson	0	0	0	0	0	0	0	0	0	0
Cosmarium sp	0	0	0	0	0	0	0	0	5360	24.699
Elakatothrix genevensis (Reverdin) Hindak	3687	0.139	0	0	0	0	0	0	0	0
Monoraphidium contortum (Thuret) Komarkova-Legenerova	0	0	0	0	2335	0.077	0	0	0	0
Monoraphidium griffithii (Berkeley) Komarkova-Legenerova	1843	0.232	0	0	0	0	0	0	21441	0.909
Monoraphidium minutum (Nag.) Komarkova-Legenerova	0	0	0	0	0	0	0	0	0	0
Monoraphidium pusillum (Printz) Kom-Legn.	0	0	0	0	0	0	0	0	0	0
Mougeotia sp.	0	0	0	0	0	0	0	0	17867	37.82
Oocystis solitaria Wittrock	0	0	0	0	0	0	0	0	0	0
Pediastrum boryanum (Turpin) Meneghini	0	0	0	0	0	0	0	0	7147	318.778
Pediastrum tetras (Ehrenberg) Ralfs	0	0	0	0	0	0	0	0	0	0
Scenedesmus acutiformis Schroeder	0	0	9884	1.863	28027	4.403	0	0	10720	1.078
Scenedesmus acutus Meyen	0	0	19769	1.987	0	0	0	0	7147	1.123
Scenedesmus bijuga (Turp.) Lagerheim	0	0	0	0	9342	1.223	0	0	0	0
Scenedesmus obliquus (Turpin) Kuetzing	0	0	0	0	0	0	0	0	0	0
Scenedesmus opoliensis P. Richter	0	0	0	0	0	0	8341	1.118	0	0
Scenedesmus quadricauda (Turpin) Brebisson	0	0	0	0	0	0	4170	1.957	14294	5.748
Scenedesmus sempervirens Chodat	0	0	0	0	0	0	0	0	0	0
Scenedesmus sp	0	0	0	0	0	0	0	0	0	0
Spirogyra sp Link	0	0	0	0	4671	126.795	0	0	0	0
Stigeoclonium sp	0	0	0	0	0	0	0	0	0	0
Tatraedron caudatum (Corda) Hansgirg	0	0	0	0	0	0	0	0	1786	0.936
XANTHOPHYCEAE										
Characiopsis sp	0	0	0	0	2335	0.235	0	0	0	0
DINOPHYCEAE										
Gymnodinium pusillum (Penard) Lemmermann	0	0	0	0	0	0	0	0	1786	8.981

Appendix 4 Phytoplankton density (number of units/L) and biomass (milligram/m3) in agricultural streams (2006)

Stream Name:	Rose Creek		Blindman R. #1		Blindman R. #2		Blindman R. #3		Strawberry Creek	
Date Sampled:	30-Aug-06		5-Sep-06		6-Sep-06		5-Sep-06		31-Aug-06	
	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass
CYANOBACTERIA										
Anabaenopsis cunningtonii R. Taylor	0	0	0	0	0	0	0	0	25525	29.236
Cylindrospermum sp	0	0	0	0	0	0	12762	3.248	0	0
Merismopedia tenusissima Lemmermann	0	0	0	0	0	0	0	0	12762	2.165
Oscillatoria limnetica Lemmerman	0	0	12762	2.245	0	0	0	0	0	0
Snowella lacustris (Chodat) Komarek et Hindak	0	0	0	0	0	0	0	0	12762	25.661
CHLOROPHYCEAE										
Ankistrodesmus gracilis (Reinsch) Kors.	0	0	0	0	51050	1.069	0	0	0	0
Ankyra judayi (G.M. Smith) Fott	0	0	12762	0.301	0	0	0	0	0	0
Chlamydomonas sp. 1	12762	1.069	0	0	0	0	0	0	0	0
Chlamydomonas sp. 2	0	0	25525	23.095	76576	69.285	25525	13.365	0	0
Crucegenia tetrapedia (Kirchner) W. & G.S. West	0	0	12762	1.711	0	0	0	0	12762	1.711
Franceia Droescheri (Lemm.) G.M. Smith	12762	0.855	0	0	0	0	0	0	0	0
Microspora sp	0	0	12762	155.89	0	0	0	0	0	0
Monoraphidium contortum (Thuret) Komarkova-Legenerova	0	0	12762	0.601	0	0	0	0	0	0
Monoraphidium griffithii (Berkeley) Komarkova-Legenerova	12762	0.902	0	0	0	0	0	0	0	0
Mougeotia sp.	12762	357.249	0	0	0	0	0	0	0	0
Oocystis parva W. & G.S. West	0	0	12762	2.406	0	0	0	0	0	0
Pediastrum boryanum (Turpin) Meneghini	0	0	12762	262.651	0	0	0	0	0	0
Scenedesmus acutiformis Schroeder	12762	2.406	0	0	0	0	12762	0.481	0	0
Scenedesmus acutus Meyen	0	0	25525	1.925	12762	5.132	0	0	0	0
Scenedesmus opoliensis P. Richter	12762	4.811	0	0	0	0	0	0	0	0
Tetraedron minimum (A. Braun) Hansgirg	12762	11.547	0	0	0	0	0	0	0	0
CHRYSOPHYCEAE										
Chromulina sp.	25525	8.554	0	0	63813	21.384	0	0	51050	17.107
Mallomonas sp	0	0	0	0	12762	8.554	0	0	0	0
Ochromonas sp	12762	4.277	25525	8.554	25525	8.554	0	0	12762	4.277
Unidentified naked Chrysophyte sp (*Ochromonas / Chromulina*)-large	76576	25.661	140389	52.725	102101	34.215	76576	30.793	102101	34.215
Unidentified naked Chrysophyte sp (*Ochromonas / Chromulina*)-small	25525	0.214	25525	0.601	38288	0.902	0	0	25525	0.601
CRYPTOPHYCEAE										
Cryptomonas erosa Ehrenberg	0	0	12762	6.843	76576	72.171	0	0	0	0
Cryptomonas marsonii Skuja	12762	13.365	38288	40.095	25525	21.384	38288	102.644	63813	171.073
Cyrptomonas phaseolus Skuja	0	0	12762	5.132	0	0	0	0	0	0
Cryptomonas reflexa Skuja	0	0	114864	259.817	63813	125.097	12762	14.702	0	0
Cryptomonas rostratiformis Skuja	0	0	0	0	12762	40.416	0	0	0	0
Katablepharis ovalis Skuja	0	0	51050	4.277	63813	5.346	0	0	12762	0.855
Rhodomonas minuta Skuja	153152	34.642	625373	141.456	612610	138.569	408407	92.379	331830	75.058
Rhodomonas minuta var. *nanoplanctonica Skuja*	51050	3.421	63813	4.277	38288	3.208	38288	2.566	38288	4.01

Appendix 4 Phytoplankton density (number of units/L) and biomass (milligram/m3) in agricultural streams (2006)

Stream Name:	Rose Creek		Blindman R. #1		Blindman R. #2		Blindman R. #3		Strawberry Creek	
Date Sampled:	30-Aug-06		5-Sep-06		6-Sep-06		5-Sep-06		31-Aug-06	
	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass
EUGLENOPHYCEAE										
Euglena cf. *minuta* Prescott	293542	157.387	561559	301.089	472220	253.188	255254	136.859	204203	109.487
Euglena sp	0	0	0	0	12762	57.737	0	0	0	0
Phacus sp	0	0	0	0	0	0	12762	21.384	0	0
DINOPHYCEAE										
Gymnodinium ordinatum Skuja	0	0	0	0	0	0	0	0	12762	8.019
Gymnodinium pusillum (Penard) Lemmermann	0	0	0	0	0	0	0	0	12762	34.054
BACILLARIOPHYCEAE (DIATOMS)										
Amphora sp	0	0	12762	2.413	0	0	0	0	0	0
Navicula sp	51050	11.946	25525	2.553	12762	14.677	12762	28.486	38288	8.27
Neidium sp	0	0	0	0	12762	4.084	0	0	0	0
Nitzschia or *Fragilaria* sp	0	0	25525	1.723	25525	4.39	0	0	0	0
Rhoicosphenia abbreviata (Agardh) Lange-Bertalot	0	0	0	0	12762	2.077	0	0	0	0
Synedra sp	0	0	0	0	12762	2.553	0	0	12762	1.149
Centric diatom	12762	1.283	63813	25.06	38288	15.036	25525	2.165	0	0
Cocconeis sp	76576	117.621	38288	68.612	51050	20.42	76576	44.012	0	0
Diatoma moniliformis Kuetzing	25525	1.838	0	0	0	0	0	0	0	0
Fragilaria capucina Desmazieres	12762	0.517	0	0	0	0	0	0	0	0